Planning Constraints

Cost-effectiveness: For each alternative, the analysis of costs and benefits allowed the computation of the alternative's net benefits and benefit-cost ratio (BCR). Both the costs and the benefits of the alternatives depend on estimated future lake levels and also on the water quality and water quantity of any outflow from Devils Lake to the Sheyenne River. For every alternative, therefore, the costs and benefits were calculated using two sets of long-term projections—one set of projections regarding the lake levels, and another regarding the water quantity and quality of flows discharging to the Sheyenne River.

In general terms, the steps of the Economic Analysis were as follows:

1. A computer model simulating the hydrology of the Devils Lake basin provided the first set of projections. These 50-year lake level projections resulted from computer-generated patterns of climate fluctuations. The climate fluctuations, along with input parameters related to the specifics of the alternative under consideration, allowed the model to produce 10,000 stochastically generated 50-year "traces" of projected lake levels. Note that for each 50-year with-project trace, it was necessary to produce a companion without-project trace to allow calculation of project costs and benefits.
2. A second water and chemical mass-balance model was developed to generate future volumes and water quality concentrations in Devils Lake and Stump Lake using the climatic inputs of the first model.
3. A third model was developed as an outlet simulation model for generating daily outlet discharges and sulfate concentrations to meet downstream water quality and water quantity constraints in the Sheyenne River.
4. A fourth computer model was used to give the projections regarding the downstream river water quality and quantity. This fourth model used the lake level trace output from the third model as input, along with climate projections and hydrologic information for the downstream rivers. In this way, normal river flows could be combined with any Devils Lake outflows to predict water quality constituent concentrations and flow rates over the same 50-year span. Again, for each with-project trace, a companion without-project trace was generated to allow calculation of project costs and benefits.
5. A fifth computer program used the lake levels and river water quality and quantity parameters to calculate the costs and damages for each of the features around Devils Lake and for each of those features downstream of the lake that could be affected by outflow from the lake. For each feature, costs and damages were summed for both the with-project and the without-project condition. An alternative's benefits could be calculated by subtracting the with-project summation of all of a feature's costs and damages from the without-project summation of all of the same feature's costs and damages. The project costs compared to these benefits provides the expected net benefits and BCR for the alternative.
6. Finally, further analysis of the alternative was desired to determine the economic indices' sensitivity to variations in the assumptions made regarding the alternative. For each alternative, therefore, additional sets of benefits and costs were computed.

Each additional set was computed after making adjustments to one or more of the following:

- Assumptions regarding the future climatic conditions.
- Assumptions regarding the simultaneous infrastructure protection measures that would be undertaken with or without the project.
- Assumptions that infrastructure protection measures would be undertaken without the project.
- Assumptions regarding the way in which the natural outlet would erode if the Devils Lake/Stump Lake system overflowed. (Altering these erosion assumptions changes the flow rate of water spilling from the lake.)

Appendix B further documents the methods, assumptions, and results of the benefit-cost analysis. In Public Law 108-7, the Congress removed the traditional requirements regarding economic justification and provided instead that the justification of the emergency outlet shall be fully described, including the analysis of the benefits and costs.

Water Quality Standards: The State of North Dakota has classified the Sheyenne River as a class 1A stream and the Red River as a class 1 stream, which establishes its designated use as suitable for aquatic life, boating and swimming, and municipal water supply use subject to treatment by softening to meet chemical drinking water requirements. The sulfate standard for class 1A streams is 450 mg/l. North Dakota has not established Total Dissolved Solids (TDS) standards for class 1 or 1A streams. North Dakota has also established an antidegradation implementation procedure that calls for a review process whenever a new or expanded source of pollutants would cause a significant permanent effect on the quality and beneficial uses of the affected waters. A determination of “significant effect” would occur if the ambient quality of any parameter were degraded by more than 15 percent, or the available assimilative capacity were reduced by more than 15 percent, or any pollutant load were to be increased by 15 percent.

The State of Minnesota’s water quality rules have established 250 mg/l sulfate and 500 mg/l TDS as standards for the Red River of the North. Other standards apply but are likely to be met whenever the TDS standard is met. Minnesota also has an antidegradation policy that affords protection of designated uses based on non-numeric criteria.

Pursuant to the 1909 Boundary Waters Treaty, the International Joint Commission has established a set of water quality objectives (not standards) for the purpose of protecting the Red River of the North entering Canada. The numeric objectives are the same as Minnesota’s numeric standards.

Downstream Channel Capacity: The nominal channel capacity for the upper reaches of the Sheyenne River has been established at 600 cfs. There are some areas of overbank flooding even at 600 cfs, which are primarily floodplains adjacent to the river. There are no major roads affected at 600 cfs, but some trail crossings during low flows would be affected. It is recognized that even a constrained operating plan that limits the total combined flow of the Sheyenne River and the Devils Lake outlet to 600 cfs at the insertion point would have impacts. Extra flows would tend to aggravate streambank erosion, increase groundwater stages, and cause flooding when localized storms increase Sheyenne River flows without an opportunity to reduce Devils Lake discharge amounts. These potential impacts have been studied and are addressed elsewhere in this report.

ALTERNATIVE PLANS

Initial Screening of Alternatives

In recent years, the Corps of Engineers has performed numerous studies on Devils Lake, and many different outlet schemes have been considered in these studies. Information used for determining alternatives came primarily from the following five reports:

- Devils Lake, North Dakota, Contingency Plan, 12 August 1996
- Devils Lake, North Dakota, Emergency Outlet Plan, 12 August 1996
- Devils Lake Emergency Outlet, Independent Assessment, Phase I, October 30, 1997
- Memorandum for Record dated 14 April 1999, Subject, "Devils Lake Emergency Outlet, Alternative Cost Comparisons"
- Devils Lake Basin, North Dakota, Integrated Draft Feasibility Report and Environmental Impact Statement, April 1988

These studies and others have evaluated various configurations and alignments of outlet plans. One of the first steps of this formulation process was to determine the best plan for each of the alternatives to be included in the formulation. This screening process is described in Appendix D. Additionally, potential alternatives that have been suggested, but eliminated from further consideration prior to this formulation process, include water treatment and relocation of improvements from the flood zone around Devils Lake.

The final cost estimates for the alternatives that will be carried forward for the detailed evaluation (pages 5-118 to 5-158) vary from the estimates used in the following alternative screening since the final cost estimates (and resulting Benefit-Cost Ratios) are developed with a greater level of detail.

<u>No Action</u>

This alternative assumes that no action is taken to protect property and infrastructure around Devils Lake if the lake continues to rise.

Most Likely Future Without Project

This alternative is a continuation of emergency flood protection measures that have been performed for infrastructure features around Devils Lake up to this time. The locations where flood damages might occur were analyzed at 24 separate features adjacent to the lake. They include communities, roads, rail lines, public facilities, and rural areas. As the most likely future, the other alternatives were compared to this future condition. This alternative was compared to the No Action alternative.

Water Treatment

Treatment of outlet water from Devils Lake has been briefly investigated in past reports. Treating lake water to reduce the total dissolved solids would allow much more water to be added to the Sheyenne River without exceeding water quality standards. Several technologies are being used today to desalinate water; all of them are very costly. Water treatment has been considered in earlier studies of the lake. Most recently the Army Corps of Engineers' Engineering Research and Development Center (ERDC) investigated the optional technologies available and provided their results in November 2002.
The treatment plant goals established for their analysis were 400 mg/l TDS, 100 mg/l SO_4^-, and 300-cfs maximum discharge. The plant would only be in operation for seven months of the year (01 May – 30 Nov) due to weather and temperature (ice) constraints. Water treatment technologies considered included membrane filtration, thermal, and chemical addition. These technologies are listed below. Ion exchange was not investigated in depth because regeneration and pH control would limit the range of TDS/sulfate levels that could be treated.

Process	Technology
Membrane Filtration	Microfiltration
	Nanofiltration
	Ultrafiltration
	Reverse Osmosis
Thermal	Distillation/Evaporation
	Freezing
Chemical Addition	Coagulation
	Chemical Precipitation

The proposed conceptual design for a desalination plant for the Devils Lake Project would consist of two steps. The first step is treatment to remove all aquatic biota and suspended solids that could foul the reverse osmosis membrane. To ensure compliance with the Boundary Waters Treaty of 1909, 100 percent of the project inflow rate (300 cfs) will be treated by microfiltration. Pretreatment to the microfiltration will utilize screens to remove debris. Following microfiltration, pretreatment will include the addition of acid and anti-scaling agents. The water will then be treated by reverse osmosis, followed by degasification, pH adjustments, and disinfection (if required) prior to discharge. Preliminary cost estimates for construction costs and annual operation costs are approximately $265 million and $27 million, respectively. The cost estimates confirm the results of investigations performed earlier.

Other sources list similarly high costs for desalinating water. On its Web page, the USGS indicates that costs for desalinization of seawater can range from $1,300 to $2,200 per acre-foot (total costs). Desalinating 150 cfs for 7 months per year would result in an annual cost of $82 million to $140 million using the USGS estimates. World Bank estimates for desalinated water are $1.60 to $2.70 per cubic meter. These unit costs would result in a yearly cost of $124 million to $210 million at 150 cfs for 7 months. Optimistic planners for desalinating seawater in the Middle East hope to get costs as low as $0.50 per cubic meter. If this could be achieved in Devils Lake, it would still result in an annual cost of $39 million. A very large desalinization plant at Devils Lake would be expected to approach the lower end of estimated costs per volume of water treated. Energy costs would be extremely high. The absolute minimum energy required to recover 1,000 gallons of fresh water is 2.98 kilowatt-hours.

There are other concerns with operating a large desalinization plant besides cost. One is finding a source for the large amount of power that would be required to run the plant. Another is finding a disposal location for the large quantities of sludge and brine that the plant would produce. This plan was dropped from the study due to both the high initial construction costs and also the high operational costs.

Relocation

Although there was not a formal evaluation of a relocation alternative for the entire Devils Lake basin, the value of buildings and infrastructure around Devils Lake was estimated in 1998 to be approximately $1 billion.[1] Relocation of most features was considered in the current economic analysis. Costs for relocation of features is dependent on the structure type and location. Isolated residential structures and outbuildings can be relocated for somewhat less than the value of the structure. Relocation of large buildings and city infrastructure may result in relocation costs that are somewhat more than the value of the structure. However, costs on the whole would not vary greatly from the value of the building or infrastructure. The value of the buildings and infrastructure, $1 billion, can therefore be used as an estimated cost for complete relocation cost around Devils Lake.

Outlet Plans

[1] Technical Report "Benefits and Costs of Alternative Emergency Outlets for Devils Lake, North Dakota: The North Dakota State Water Commission Temporary Emergency Outlet and the US Army Corps of Engineers Permanent Emergency Outlet." Prepared by Hazard Mitigation Economics Inc., September 27, 1999.

Many outlet studies have been conducted in the past, and these studies were used as a starting point to determine nine basic potential outlet alternatives. All of the proposed outlets discharge water from Devils Lake into the Sheyenne River. A complete description of the outlet alternatives for this initial screening, including the initial costs estimates, can be found in Volume II, Appendix D, "Initial Screening." Following are brief descriptions of the outlet alternatives and the results of the screening process. Three of the nine basic outlet alternatives were carried forward for additional analysis.

Three different basic outlets that draw water from the West Bay were considered:

West Bay Alternative 1. Pump Along Twin Lakes Route from West Bay

This alternative has been investigated extensively in the past because it is the shortest and lowest route for pumping water from the West Bay of Devils Lake to the Sheyenne River. The Corps of Engineers developed a preliminary design for this outlet in 1996. This alternative was dropped from this study for the same reason it was dropped in 1996, because it ran across tribal trust lands and was opposed by the Spirit Lake Nation.

West Bay Alternative 2. Pump Along Peterson Coulee Route from West Bay

This outlet from West Bay is a pipeline that begins south of Minnewaukan and runs over the divide and along Peterson Coulee to the Sheyenne River. It was substantially developed by the Corps of Engineers in 1998. This outlet alternative was carried forward for more detailed analysis.

West Bay Alternative 3. Gravity Flow Pipelines from West Bay

For this alternative, a gravity flow tunnel would be constructed from Devils Lake to the Sheyenne River. This plan was dropped because of the very high initial cost.

Pelican Lake Alternative

One outlet alternative was considered that draws water from Pelican Lake. A channel would carry water to a pump station near Minnewaukan where it would be pumped into a pipeline that would run over the divide and along Peterson Coulee to the Sheyenne River. This plan has the potential to be able to pump more water from the lake than any other outlet plan while meeting downstream water quality targets. This outlet alternative was carried forward for more detailed analysis.

Four outlets were considered that would draw water from East Devils Lake:

East Devils Lake Alternative 1. Gravity Flow Along Tolna Coulee from East Devils Lake

For this alternative, a channel would be dug from East Devils Lake to a daylight point in Tolna Coulee where water would naturally flow to the Sheyenne River. Drop structures would be needed to control erosion at the lower end of the channel. This alternative was dropped because of expected low effectiveness and because it would cost more than other East Devils Lake alternatives.

East Devils Lake Alternative 2. Pump from East Devils Lake to Tolna Coulee

This alternative is virtually the same as the previous alternative but incorporated a low head pump station to pump water up to a higher outlet channel to reduce the required excavation and therefore make the initial cost lower. It was dropped for the same reasons as the previous alternative.

East Devils Lake Alternative 3. Gravity Flow Tunnel from East Devils Lake

For this alternative, a gravity flow tunnel would be constructed from Devils Lake to the Sheyenne River. It was dropped from the study due to high initial costs and for the reasons stated in the previous East Devils Lake Alternatives.

East Devils Lake Alternative 4. Gravity Flow Channel from East Devils Lake to Stump Lake Outlet

For this alternative, the outlet from the east end of Devils Lake would be a grass-lined gravity flow channel that initially would follow the natural overflow channel between Devils Lake and Stump Lake. At Stump Lake, the channel would follow the west side of the lake until it reached the natural outlet from Stump Lake. From there it would continue along the natural Stump Lake outlet route until the channel invert intersected natural ground in Tolna Coulee. From there, Devils Lake water would flow down Tolna Coulee into the Sheyenne River. This outlet route does not cross the Spirit Lake Reservation. <u>This alternative was carried forward for further analysis because it is the least costly of the East Devils Lake alternatives.</u>

West Stump Lake Alternative

For this alternative, a channel would be constructed from West Stump Lake to a daylight point in Tolna Coulee. This alternative was dropped because of the very poor quality of the water in Stump Lake and because it requires Stump Lake to be filled before it is able to affect the level of Devils Lake, which also would impact the Stump Lake National Wildlife Refuge.

<u>Expanded Infrastructure Protection</u>

There are several locations around Devils Lake in which roads are currently holding back water, providing barriers to the rising and expanding waters of Devils Lake. Since these roads are acting as dams, but are not constructed to function as dams, there is a potential safety hazard to road users and to the people living behind these barriers and using the areas which they shelter. This alternative examines the economic feasibility of taking additional measures to provide a safe level of flood protection behind these barriers.

Upper Basin Storage

Basin water management has long been recognized as a viable and valuable component of Devils Lake flood control. The North Dakota State Water Commission (NDSWC) considers it an integral element of the recommended overall flood control package along with infrastructure protection and an outlet. For example, this three-pronged approach is cited in the Devils Lake Basin Water Management Plan as a necessary and comprehensive approach to alleviate flooding in the basin.

In the context of Devils Lake's flooding, the goal of basin water management is to reduce the volume of runoff that reaches Devils Lake. The focus has been on upper basin storage; however, comprehensive basin water management encompasses a range of activities that can help retain water in the upper basin, including restoring wetlands, creating new holding ponds, eliminating illegal drains, and changing farming practices. Examples of the latter include conservation tillage to retain more moisture in the soil profile, converting cropland to grass or another permanent cover, and manipulating gates on field drains to control flows, especially in the spring, to allow additional water to percolate into the soil. Side benefits from such water management measures accrue to a multitude of interests – reducing sheet erosion, increasing crop production, improving water quality, increasing wildlife habitat, and reducing flooding.

In looking at the implementability of basin water management measures to reduce Devils Lake flooding, it is important to recognize potential adverse impacts from these measures. For instance, farmers may readily agree to store water in a low spot that has been too wet to till for years. However, they are not likely to store water on previously dry land that would take pasture or crop acreage out of production on top of what has already been lost to flooding. The latter has an added negative impact on other elements of the local, agriculture-based economy. Also, landowners note that percolation from retention sites raises the water table, which often brings salts to the surface in the vicinity of the storage site, adversely affecting future crop production. Water storage may also limit access to other fields, increase input or costs, lead to additional depredation, and increase weed problems. Such problems, real or perceived, make the acceptance of such measures on a voluntary and even a compensated basis difficult for the landowner.

Currently, there are numerous Federal, State, and Local programs focused on basin water management. Many of these programs are documented in more detail in Appendix A. The most significant of these programs have been the NDSWC Available Storage Acreage Program (ASAP), the U.S. Fish and Wildlife Service storage programs, the ND Natural Resource Wetlands Trust (NDNRT) program, and the Farm Service Agency Conservation Reserve Program (CRP). No detailed study has been done to estimate the direct effect on Devils Lake levels that these programs may have collectively; however, on the basis of the studies done, a reasonable estimate would be 35,000 acre-feet, which is nearly 4 inches at current lake levels. Because of the large volume of water in Devils Lake and the lake's large surface area, significant upper basin storage or land use conversion that would eventually reduce runoff would be needed to have an impact on lake levels.

In addition to these formal programs, there is substantial, unquantified storage from existing wetlands, changed tillage practices, and land inundated during the current wet cycle. The Farm Services Agency estimates that over 300,000 acres of farmland in the Devils Lake basin has been rendered unproductive due to wet conditions since 1992. This figure is corroborated by satellite imagery covering about 3,000 square miles (79 percent) of the Devils Lake Basin. On the basis of imagery taken on 17 August 1992, prior to the recent lake rise, the lake itself was about 44,000 acres in size and the area covered by water in the upper basin was nearly 43,000 acres. Imagery taken on 14 July 1997 showed the lake had doubled in size to over 88,000 acres, and the area covered by water in the upper basin had more than tripled to about 152,000 acres.

While some have proposed changes in land use or cropland practices as a measure to help reduce runoff volume to Devils Lake, there has been speculation that the recent rise in Devils Lake levels may be due to changes in farm practices or management in the upper basin. To assess the land use and cropland that exists in the watershed, the Corps queried the National Agricultural Statistics Service (NASS) for the basin. There does not appear to be a correlation between changes in farm practice in the basin and the recent rise in Devils Lake levels. However, there has been some decrease in cropland due to inundation. Outside of typical crop rotation, there appears to be no significant change in crop patterns, except for the increase in CRP land in the basin.

The conversion of cropland to CRP cover can significantly increase infiltration from rainfall events. The cover also has the ability to trap and hold snow, which provides benefits to runoff reduction from snowmelt runoff. This change would reduce runoff to Devils Lake, although not significantly since only 8 percent of the contributing area to Devils Lake is in CRP.

One basin water management measure proposed is a change in farming practice. Cropland in the basin currently comprises approximately 1,100,000 acres. If all this land were converted to CRP (as a best-case scenario), the estimated reduction in average annual runoff is 63,000 acre-feet (assuming a 0.69-inch reduction per acre from Appendix A). The impact on the stage of Devils Lake, assuming this best-case scenario and a direct response on the lake, would be a reduction in stage of 0.5 foot at current lake levels.

Irrigation is another basin water management measure that could be used to attenuate the rise of Devils Lake levels. Drawing water directly from the lake, or from upper basin storage areas that would eventually drain into the lake, would have potentially dual benefits – reduced damages at the lake and increased agricultural production within the basin. A concern about the viability of this alternative is that when irrigation is needed, the lake or storage areas may be in recession. Conversely, when Devils Lake is high, the basin is likely to be saturated with standing water in prairie potholes and irrigation would not be needed or feasible. Another concern is the suitability of soils and water for irrigation. Some soils should not be irrigated, and conditional soils should be irrigated under a high level of management, otherwise permanent damage to the soil could result. Source water high in salinity could also potentially damage the soil.

Reducing runoff excess by only 1 inch from the land in the basin would have a significant effect on Devils Lake levels if it were basin wide. Although this measure may seem to be small, this option may not be implementable or feasible. There is approximately 1,700 square miles of cropland in the basin. If an incentive of only $20 per acre were proposed through a farm policy program, the cost would be $20 million per year. Although irrigation may have some benefit, it may be limited because the land may already be saturated. A prudent approach to more thoroughly examine the effectiveness of irrigation would be a small test project in the upper basin. This coincides with the direction being pursued by the Devils Lake Basin Joint Water Resource Board, as recommended in an August 2002 report entitled " Reconnaissance Level Investigation". Upper basin water management is discussed in more detail in Appendix A.

Intermediate Array of Alternatives

Alternatives developed and evaluated are described in this section. Costs for most of the alternatives are shown in Table 5-3. Costs for the other alternatives are listed with the description of the alternative. Figure 5-4 shows the Devils Lake Basin and the general location of features that are described. Outlet alternatives from the West Bay of Devils Lake are shown in more detail on Figure 5-5.

No Action

This alternative, which is also referred to as the Infrastructure Protection Plan, assumes that no action will be taken to protect property and infrastructure around Devils Lake if the lake continues to rise. This was used as the future condition to be compared to the Most Likely Future Without Project.

Most Likely Future Without Project

This alternative is a continuation of emergency flood protection measures that have been performed for infrastructure features around Devils Lake up to this time, and was used as the base condition that other alternatives were compared to. It was also compared to the No Action alternative. To evaluate future flood protection measures in the Devils Lake area, it was first necessary to develop a list of features for which flood protection efforts were likely. Developing the list required judgment as to which structure and infrastructure components might be grouped under a single feature. It also required an evaluation of the likely damages to the various roads, railroads, and other entities in the Devils Lake area. Discussions with local, state, and federal officials provided essential information regarding which features were most critical, which could reasonably be protected, and which were more likely to be abandoned should the water continue rising.

For this study, 24 significant independent features were selected based on the threats from flooding and the potential for protection. The features were grouped into five types: communities and cities, certain state facilities, rural areas, roads, and rail lines. Figure 5-3 shows the location of all 24 features. The table following Figure 5-3 lists the features and shows how they are grouped by type for the analysis.

Dependencies and Attributes of Features

The individual features were generally evaluated independently in the feature analysis. For instance, communities were evaluated independently from the roads that provide access to the communities. The following section describes the physical dependencies of the features, emergency actions taken to date, and attributes of the features.

Communities and Cities: Of the 24 selected independent features, five were communities or cities: Churchs Ferry, Devils Lake, Fort Totten, Minnewaukan, and St. Michael. Each of these is home to local residents, and each has significant economic importance because of the relative density of infrastructure in this predominantly rural area of North Dakota. It was determined that all infrastructure (such as wastewater treatment facilities, schools, grain elevators, hospitals, schools, and airports) within the communities was dependent on the flood protection provided for the community. Therefore, such infrastructure was not treated separately; local infrastructure was considered simply as a part of the community or city feature.

State Facilities: Two of the selected features are state-owned facilities: Gilbert C. Grafton Military Reservation and Grahams Island State Park. The operation of the military base has a significant local economic impact. Rising lake levels were determined to have potential for substantial adverse impact on the access and use of the facility. A substantial amount of land used for military maneuvers at the base has been inundated in recent years. The base has also been forced to pump water from the west side of ND Highway 20 (just south of the City of Devils Lake levee) to protect several training areas.

Grahams Island State Park is a major tourist attraction in the Devils Lake area. Park staff estimate that a total of 73,770 visitors used the park during 1999. Access to the park is affected by rising lake levels; the park was closed in 1997 when the access road was under water. During 1997, approximately $2.2 million was invested in raising the access road to the park.

Rural Areas: The rural areas adjacent to the lake, including farmsteads and farmland, residences, small towns, and small parks, were combined into this feature. Although the cost of individual infrastructure and land in these rural areas is not high, the total impact of rising lake levels on rural areas is significant. Because Stump Lake water levels could be significantly lower than those of Devils Lake, the rural areas around Stump Lake were treated separately from those adjacent to Devils Lake.

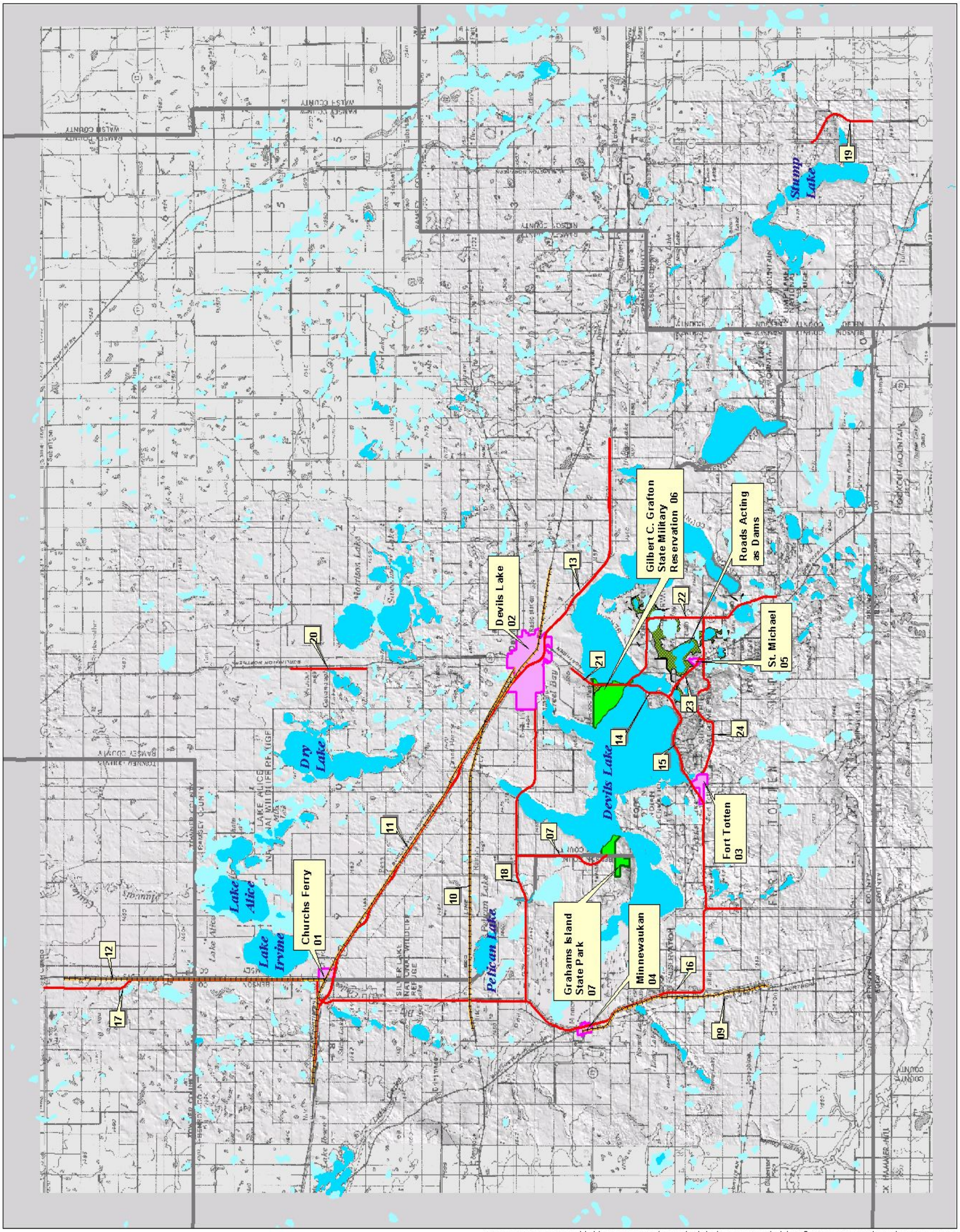

Figure 5-3: Features Adjacent to Devils Lake

List of Features Selected

Communities and Cities: (includes wastewater treatment facilities, hospitals, and schools)

1. Churchs Ferry
2. City of Devils Lake
3. Fort Totten
4. City of Minnewaukan
5. St. Michael

State Facilities:

6. Gilbert C. Grafton State Military Reservation
7. Grahams Island State Park

Rural Areas:

8.1 Devils Lake Rural Areas
8.2 Stump Lake Rural Areas

Rail Lines:

9. Red River Valley and Western Railroad: Minnewaukan South (note: this rail line has been abandoned)
10. Canadian Pacific Railroad: City of Devils Lake to Harlowe
11. Burlington Northern Railroad: Along US Highway 2
12. Burlington Northern Railroad: Churchs Ferry to Cando

Roads:

13. US Highway 2
14. Highway 57 between Highway 20 and BIA 1
15. Highway 57 between BIA 1 and Highway 281
16. Highway 281 South of US Highway 2
17. Highway 281 North of US Highway 2
18. Highway 19 from the City of Devils Lake Levee to Highway 281
19. Highway 1
20. Highway 20 North of the City of Devils Lake
21. Highway 20 from the City of Devils Lake Levee to Highway 57
22. Highway 20 between Highway 57 and Tokio
23. BIA 1 between Highway 57 and BIA 6
24. BIA 6 between Highway 20 and Fort Totten

For more detail on these features, please refer to *Devils Lake Infrastructure Protection Study, January 2003*, by Barr Engineering.

Rail Lines: Four rail lines in the area were initially selected as independent features because they would be affected by the rising lake levels. However, the Red River Valley and Western spur line to Minnewaukan was subsequently closed so that further analysis was not necessary. The Burlington Northern line that runs parallel to US Highway 2 is a major artery in the Upper Midwest's railroad system. Trains using this rail line have routes that connect New York to the state of Washington. Many local communities outside of the study area are also dependent on this rail line, although the communities themselves are on high ground. The other two rail lines that were selected as features are spur lines whose main function is to provide service to local grain elevators, and to deliver fertilizer to the area. Because of flood damage, the Canadian Pacific Railroad line from the City of Devils Lake to Harlowe was closed in 1998.

Roads: There were 12 sections of roads that were selected as independent features. The selection of road sections was based on the results of a recent study[1] of transportation patterns in the region. Roads were typically selected if they had average daily traffic counts (ADTs) greater than 1,000 prior to the recent increases in lake level. The roads included as independent features are described below.

A. US Highway 2 is an important regional transportation route. Both interstate travel and local communities outside of the study area would be adversely affected by the closing of this road. The low portions of US Highway 2 are currently protected by the City of Devils Lake levee.

B. Two other roads that are heavily used for east-west travel in the area are ND Highway 57 and ND Highway 19. The lowest portions of both of these roads have been raised in recent years to maintain east-west travel.

C. There are three major highways used for north-south travel in the area: US Highway 281, ND Highway 20, and ND Highway 1. The lowest portions of Highway 281 and ND Highway 20 have been raised in recent years to ensure uninterrupted north-south travel. ND Highway 1, located near Stump Lake, had been threatened by the rising water of Stump Lake until it was realigned in 2001.

D. Two roads on the Spirit Lake Nation Reservation had average daily traffic counts greater than 1,000: BIA Highway 1 and BIA Highway 6. The lowest portions of both of these roads have been raised in recent years to maintain travel in the area.

E. Three of the highways (ND Highway 57, US Highway 281, and ND Highway 20) were subdivided into multiple sections, and each section was treated as a separate feature. Considering the sections individually allows economic modeling to account for different traffic patterns, different potential reroute paths, and different lake elevations at which each of the road sections would be affected by flooding.

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[1] *Devils Lake Flood Control, Economics Database Update: Transportation Report*, Barr Engineering Company, January 1998.

Adjacent Lake Features Not Independently Analyzed

Several facilities or infrastructure that were not analyzed as independent features are discussed below:

A. ***Community of Penn:*** The community is at about elevation 1460 and would become isolated by the lake at approximately lake level 1457. It is located adjacent to US Highway 2 and is dependent on it for access at high lake levels. The population of the community is estimated to be just under 150 and was included in Feature 8.1: Devils Lake Rural Areas.

B. ***Spirit Lake Casino:*** The casino is above elevation 1463, so it would not be damaged directly by the rising lake.

C. ***Other Parks and Recreation Areas:*** Other parks and recreation areas in the region, including Shelver's Grove, Black Tiger Bay, and Settler's Park, were included in Feature 8.1: Devils Lake Rural Areas and Feature 8.2: Stump Lake Rural Areas. These facilities are similar to Feature 7: Grahams Island State Park, in that the infrastructure would likely be relocated.

D. ***Water Supply Systems:*** The City of Devils Lake wells are located on high ground south of Tokio and the Ramsey County Rural Utility wells are located on high ground south of Tolna. The community water treatment facilities would be affected with the respective community and were included in the respective feature.

E. ***Power and Utilities:*** Power and utility lines throughout the area were analyzed with Feature 8.1: Devils Lake Rural Areas and Feature 8.2: Stump Lake Rural Areas.

F. ***Wastewater Treatment Plants:*** Wastewater treatment plants would be affected with the respective community and were included in the respective feature.

G. ***Hospitals and Schools:*** Hospitals and schools would be affected with the respective community and were included in the respective feature.

H. ***Devils Lake Municipal Airport:*** The Devils Lake Municipal Airport is currently protected by the City of Devils Lake levee. The airport would be affected with the city and was, therefore, included in Feature 2: City of Devils Lake.

I. ***Woods-Rutten Road:*** Prior to the rising lake level, this road had an average daily traffic (ADT) count of less than 200, well below the ADT criterion of 1,000 to qualify as a feature. The recent transportation study indicated that this road was not a primary route. Also, at higher lake levels, this road would require a significant raise to remain open. Therefore, this road was not included in the study.

J. ***Ramsey County 4:*** Prior to recent high lake levels, this road had an average daily traffic (ADT) count of less than 200, well below the ADT criterion of 1,000 to qualify as a feature. The recent transportation study shows results similar to Woods-Rutten Road. Ramsey County 4 is higher than Woods-Rutten Road, and was analyzed as a reroute for Highways 20 and 57. However, it would also require a significant raise to remain open at high lake levels.

K. ***BIA 4 and BIA 5:*** These BIA roads were raised in recent years to remain open to local traffic and have been used as reroutes for other closed roads in the area. However, the ADT on these roads prior to the flooding was about 200, well below the ADT criterion of 1,000 to qualify as a feature. Furthermore, the recent transportation study indicated that these roads were not primary routes. Therefore, they were not included in the study.

Selection of Flood Protection Strategies

To analyze the economic feasibility of each project, the features were combined using the set of Most Likely Action Flood Protection Strategies. The most likely action for each feature assumes that the types of emergency measures currently being pursued in the basin would continue to be implemented as necessary as the lake continues to rise. This set of most likely action strategies was assumed to be the baseline condition for this study, meeting the National Economic Development (NED) criteria as "the most likely condition expected to exist in the future in the absence of a proposed water resources project." These emergency measures include such actions as raising the levees protecting the City of Devils Lake and relocating homes if the lake level continues to rise. For example, if a road has been raised in recent years, it is likely that it will continue to be raised.

Decision Trees: The strategies for each feature can be graphically represented as "decision trees" showing decisions that would be made and actions that would be taken at various critical elevations. A decision tree was developed for each feature. The decision trees indicated the lake elevations at which decisions and actions would be required, and showed the options that were analyzed at those levels.

Action Levels: The lake level at which a decision must be made is called an action level. For the Economic Analysis, action levels were assumed to occur 1 foot below the "design level of protection" in order to provide lead time for construction of protection measures before damages would occur. The design level of protection was defined separately for each feature and for each of the various flood protection measures.

The flood protection strategies that were analyzed for the various feature types are described below.

Communities and Cities: The most likely action strategies for communities and cities is typically incremental protection in the form of levee raises or relocation of structures. For Devils Lake and Minnewaukan, the most likely action is incremental levee raises. For Churchs Ferry, Fort Totten, and St. Michael, the most likely future is incremental relocations.

State Facilities: The most likely action strategies for state facilities would be incremental protection. The most likely flood protection strategy for Grahams Island State Park was raising the park's access road and relocating any low structures in a series of increments. A levee was not considered feasible for the facility because of the relatively low value of infrastructure there.

The majority of infrastructure at the Gilbert C. Grafton State Military Reservation facility is located above elevation 1463. The incremental strategy assumed for this facility was access road raises, construction of a levee to protect the munitions storage area, and construction of a ring dike to protect structures in a series of increments.

Rural Areas: For the rural areas, the only viable strategy was relocation of the structures to high ground and the loss of the value of inundated property. The infrastructure in these areas is scattered and could not be effectively protected because of the relatively high costs and the lack of access during high lake levels.

Rail Lines: The most likely action strategy for rail lines is typically incremental protection, involving railroad raises in a series of incremental steps. The Red River Valley and Western Railroad has been abandoned.

Roads: The most likely action strategies for roads is typically incremental protection, involving a series of road raises. The maximum protection strategy for roads could be either raising the road to elevation 1468 or rerouting the road along a new alignment at the first decision/action level. Rerouting of roads was considered feasible for three roads: Highway 1 (assumed to have already occurred), Highway 281 south of US Highway 2, and Highway 281 north of US Highway 2.

Selected Flood Protection Strategies

Table 5-2 summarizes the features and most likely flood protection strategies.

West Bay Outlet (Peterson Coulee)

Alternative outlet alignments considered are shown on Figure 5-4. Most outlet alternatives that have been seriously developed in the past have drawn water from the West Bay of Devils Lake. This area has the best water quality in the area of the lake that is located relatively near the Sheyenne River. Because of opposition from the Spirit Lake Tribe over the shorter, lower Twin Lakes route, an outlet that incorporates Peterson Coulee is the recommended route from the West Bay. In 1998, a 300-cfs capacity outlet along this route was substantially designed and developed using a pipeline to convey water from Devils Lake to the Sheyenne River. This configuration minimizes impacts

Table 5-2: Infrastructure Strategies

Feature Description	Most Likely Action Strategy
Communities and Cities (includes wastewater treatment facilities, hospitals, and schools)	
1. Churchs Ferry	Incremental Relocations
2. City of Devils Lake	Incremental Levee Raises
3. Fort Totten	Incremental Relocations
4. City of Minnewaukan	Incremental Levee Raises
5. St. Michael	Incremental Relocations
State Facilities	
6. Gilbert C. Grafton State Military Reservation	Incremental Road and Levee Raises
7. Grahams Island State Park	Relocate Structures and Raise Access Road
Rural Areas	
8.1 Devils Lake Rural Areas	Structure Relocation
8.2 Stump Lake Rural Areas	Structure Relocation
Rail Lines	
9. Red River Valley and Western Railroad: Minnewaukan South	N/A
10. Canadian Pacific Railroad: City of Devils Lake to Harlow	Incremental Rail Raises
11. Burlington Northern Railroad: Along US Highway 2	Incremental Rail Raises
12. Burlington Northern Railroad: Churchs Ferry to Cando	Incremental Rail Raises
Roads	
13. US Highway 2	Incremental Road Raises
14. Highway 57 between Highway 20 and BIA 1	Incremental Road Raises
15. Highway 57 between BIA 1 and Highway 281	Incremental Road Raises
16. Highway 281 South of US Highway 2	Incremental Road Raises
17. Highway 281 North of US Highway 2	Incremental Road Raises
18. Highway 19 from the City of Devils Lake Levee to Highway 281	Incremental Road Raises
19. Highway 1	Relocate Road
20. Highway 20 North of the City of Devils Lake	Incremental Road Raises
21. Highway 20 from the City of Devils Lake Levee to Highway 57	Incremental Road Raises
22. Highway 20 between Highway 57 and Tokio	Incremental Road Raises
23. BIA 1 between Highway 57 and BIA 6	Incremental Road Raises
24. BIA 6 between Highway 20 and Fort Totten	Incremental Road Raises

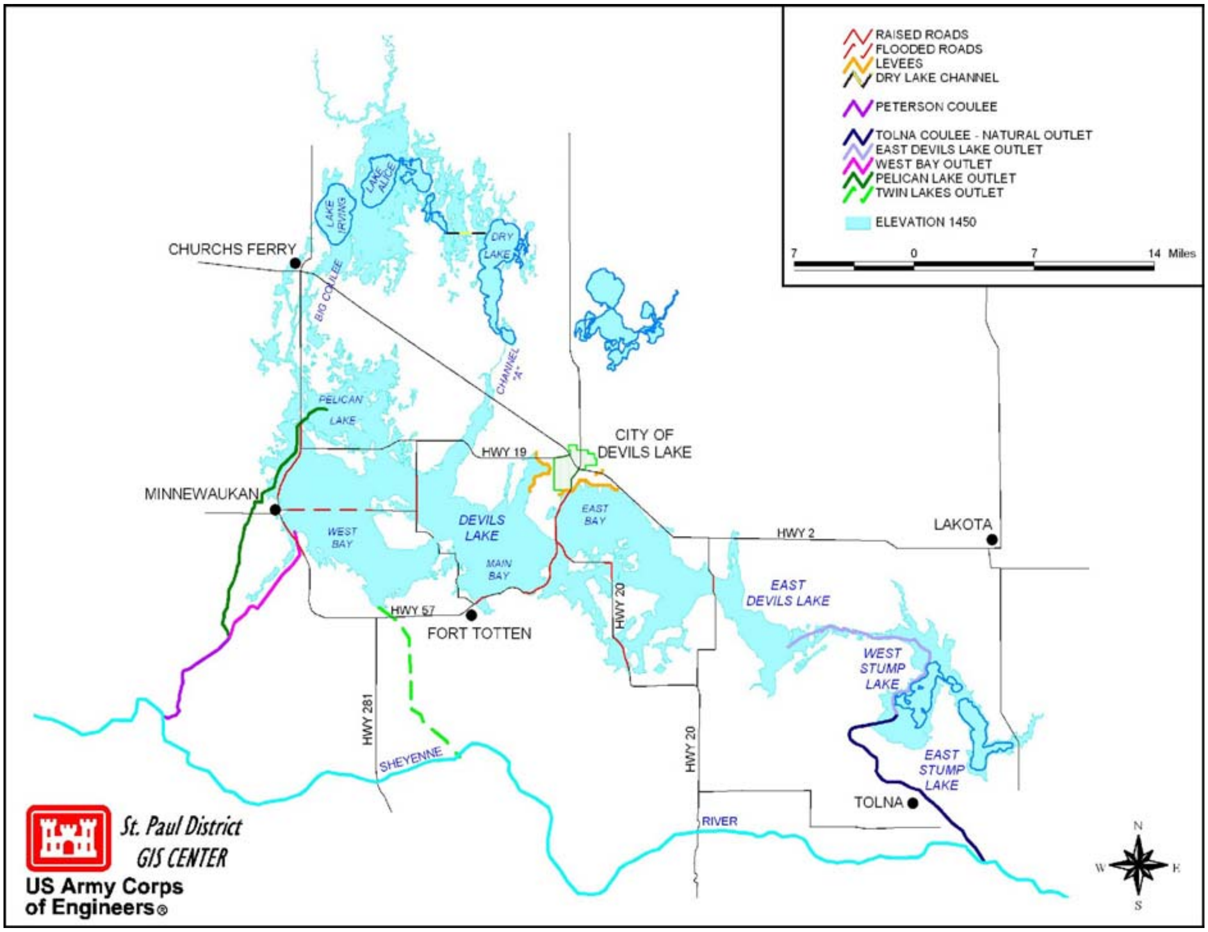

Figure 5-4: Devils Lake Basin

along the outlet route in exchange for moderate increases in estimated construction costs over open channel alternates. This outlet alternative has a total length of about 14 miles and crosses the divide at approximately elevation 1570 feet above mean sea level (msl).

The northernmost 1½ to 2 miles of this route lie within the Fort Totten Indian Reservation, but there are no impacts to Tribal trust lands because affected reservation lands are all in private ownership.

The West Bay outlet (see Figure 5-5) alternative requires a high head pump station to convey water through the pipeline. The pump station would be constructed east of Round Lake and Highway 281 to draw water from Devils Lake and convey it under the highway and over the divide to the Sheyenne River. The underground pipeline would extend from the pump station on Devils Lake to the Sheyenne River and is approximately 70,100 feet (13.3 miles) long. The first high-pressure section, approximately 14,000 feet long, would be either ductile iron pipe or steel pipe and the remainder would be reinforced concrete pipe. See Table 5-3 for costs for this alternative. The section of pipeline that runs down Peterson Coulee could be replaced by open channel flow over a series of drop structures.

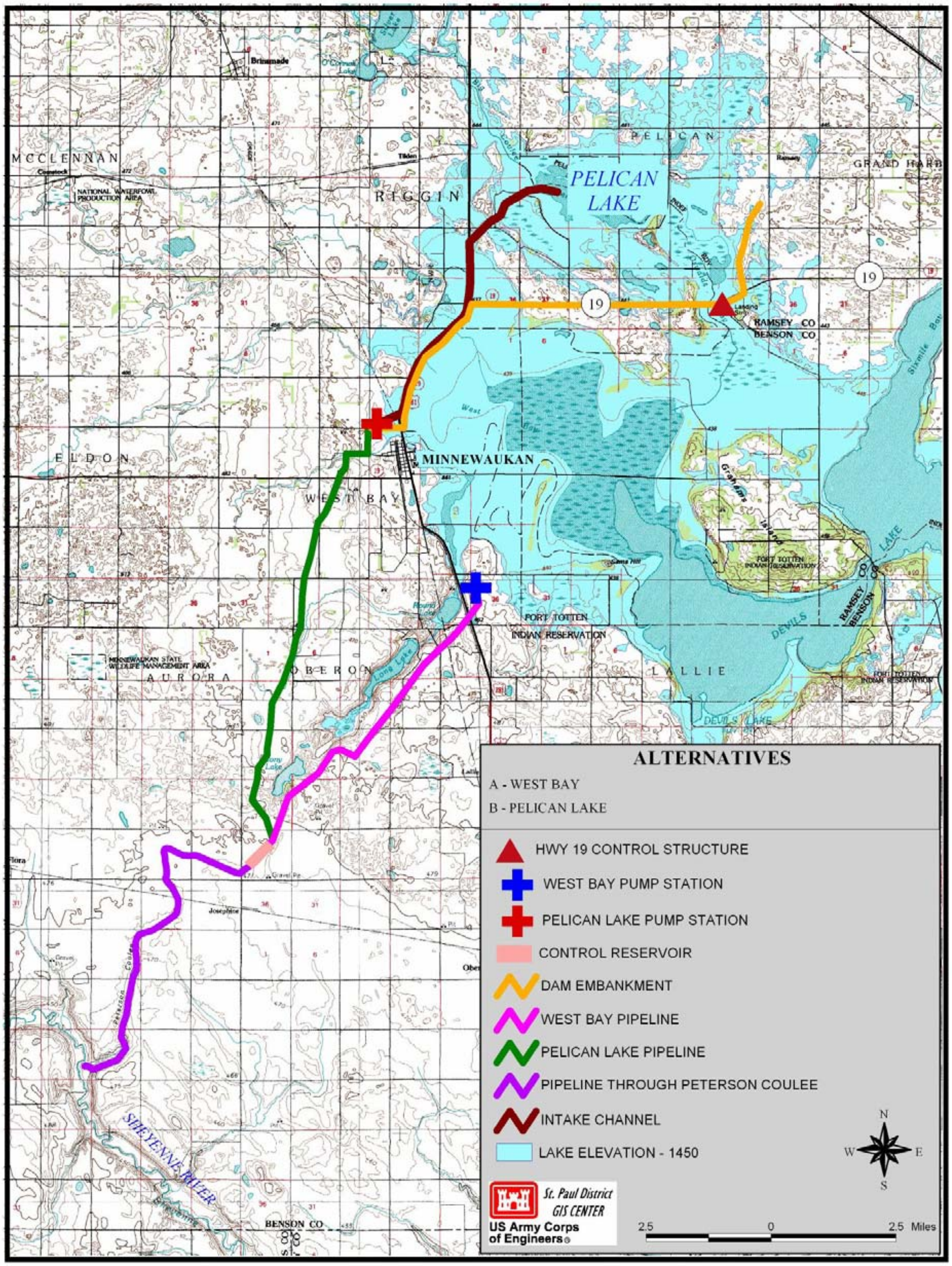

Figure 5-5: West End Alternative Features

Table 5-3: Alternative Costs

Alternative/Location	WEST BAY		PELICAN LAKE				EAST DEVILS LAKE	RAISE NATURAL OUTLET
	Base Plan		PL 1		PL 2	PL 3		
Pump Capacity	300 cfs	480 cfs	300 cfs	480 cfs	480 cfs	480 cfs	480 CFS	OUTLET
Target Sulfate Constraint in Sheyenne River	450 mg/l	none	450 mg/l	none	250 mg/l	250 mg/l	none	NA
Construction Features								
Pump Station								
Pump Station Mobilization	442,875	708,599	442,875	708,599	708,599	708,599		
Civil/Site Layout	3,996,416	6,394,266	3,996,416	6,394,266	6,394,266	6,394,266		
Electrical	3,585,175	5,736,281	3,585,175	5,736,281	5,736,281	5,736,281		
Pump & Motor Building	5,852,271	9,363,634	6,244,532	9,991,040	9,991,040	9,991,040		
Valve & Electrical Building	2,699,426	4,319,082	2,699,426	4,319,082	4,319,082	4,319,082		
Pipeline (note 6)								
Mobilization	73,812	105,446	84,357	105,446	105,446	105,446		
3-48" DIP	10,049,036	14,911,166	19,897,723	29,524,973	29,524,973	29,524,973		
Manifold	52,723	84,357	52,723	84,357	84,357	84,357		
84" RCPP	10,692,258	16,838,725	12,052,516	18,980,340	18,980,340	18,980,340		
84" RCPP	7,455,056	13,708,023	7,455,056	13,708,023	13,708,023	13,708,023		
Flow Control Reservoir	1,571,150	1,571,150	1,571,150	1,571,150	1,571,150	1,571,150		
72" RCPP	2,340,909	3,163,390	2,340,909	3,163,390	3,163,390	3,163,390		
66" RCPP	2,298,730	4,217,853	2,298,730	4,217,853	4,217,853	4,217,853		
Outlet	137,080	210,893	137,080	210,893	210,893	210,893		
Pelican Lake Features								
Inlet Channel from Pelican Lake to Pump Station			7,339,065	11,742,504	9,821,271	9,821,271		
Embankment Work for Lake Elevation up to 1454			2,513,841	2,513,841	35,770,560	35,770,560		
Block Culverts in Hwy 19 & 281			43,233	43,233	43,233	43,233		
Highway 19 Control Structure					4,260,032	4,260,032		
Dry Lake Outlet Channel (Channel A diversion)			1,246,376	1,246,376	1,246,376	1,246,376		
TOTAL CONSTRUCTION COST (2001 Dollars)	51,247,000	81,333,000	74,001,000	114,262,000	148,611,000	148,611,000	42,600,000	1,100,000
Planning, Eng., and Design	3,000,000	4,761,000	4,332,000	6,689,000	8,700,000	8,700,000	5,112,000	127,560
Supervision and Administration 6.0%	3,075,000	4,880,000	4,440,000	6,856,000	8,917,000	8,917,000	2,769,000	69,000
Project Environmental, Cultural Mitigation	1,000,000	1,000,000	1,000,000	1,000,000	9,740,000	20,949,200	4,943,000	10,000
Project Real Estate (note 3)	218,000	218,000	978,000	978,000	1,094,000	25,042,000	1,983,000	27,661,000
Downstream Environmental Mitigation	12,900,000	40,700,000	12,900,000	40,700,000	12,900,000	12,900,000	40,700,000	0
Downstream Water Treatment Plant Upgrade	0	15,000,000	0	13,000,000	0	0	40,000,000	0
Infrastructure and Lands for Project Created Lake Flooding						61,785,601		282,750,440
TOTAL PROJECT FIRST COST	71,440,000	147,892,000	97,651,000	183,485,000	189,962,000	286,904,801	138,107,000	311,718,000

STOCHASTIC FUTURE ANNUAL COSTS

Annual Operation and Maintenance	425,200	784,000	633,000	934,000	1,045,840	1,014,850	35,000	
Additional Annual Downstream Water Treatment Costs (Note 4)	35,516	3,179,233	43,510	2,259,708	43,510	43,510	3,355,768	
Environmental Monitoring	650,000	650,000	650,000	650,000	700,000	700,000	650,000	

WET FUTURE ANNUAL COSTS

Annual Operation and Maintenance (note 2)	954,800	1,638,000	1,145,000	1,800,000	1,815,000	1,924,000	35,000	74,000
Additional Annual Downstream Water Treatment Costs	92,600	3,668,100	50,600	2,590,800	30,400	33,500	3,816,000	0
Environmental Monitoring	650,000	650,000	650,000	650,000	700,000	700,000	650,000	0

NOTES

1 **This cost information is to the reconnaissance level of detail and should be used only for comparison of alternatives.**
2 Annual O&M cost considers equipment replacement, operator/maintenance workers and inspection, electric power, and all other average annual O&M.
3 Project Real Estate easements are costs only for easements along the footprint of the outlet itself. Project-related flooding costs on the Sheyenne River are not included in this table, but are included in the economic analysis
4 Water treatment cost for the East End Outlet, Stochastic future was not computed, it was extrapolated from the Wet Future cost and the other alternatives
5 Infrastructure raise costs are costs for raising roads, railroads, etc around the Devils Lake Basin that would be impacted in areas with water levels increased by the project.
6 Pipe sizes shown are for the 300-cfs West Bay Pump Station. Costs for other outlets were extrapolated from the 300-cfs West Bay outlet costs.

However, past evaluations of this feature have concluded that the pipeline is preferred over the open channel. Further discussion of the selection of 300 cfs and 480 cfs as the outlet capacities being considered is provided in Appendix A.

300 cfs Constrained Flow

The outlet developed in 1998 was designed to be able to discharge a maximum of 300 cfs. It was also designed to operate at less than full capacity in order to meet water quality and channel capacity limits at the insertion point on the Sheyenne River. The standard for maximum sulfate concentration in the Sheyenne River is 450 milligrams per liter (mg/l) and the nominal channel capacity for the upper reaches of the Sheyenne River is approximately 600 cfs. In order to stay below these limits and still pump at maximum efficiency for drawing down Devils Lake, a pumping system is required that can provide highly variable quantities of flow. For the 1998 design, the pumping station design incorporated many small (10 cfs) and medium (50 cfs) size pumps in order to be able to provide the increment of flow desired. The many smaller pumps were used because the electrically driven pumps can be readily varied by only a small percentage from their rated capacity. It is recognized now that a much less costly pump station could be constructed using just a few large pumps, such as three 100-cfs pumps. Constructing a small reservoir area just before the pipeline enters Peterson Coulee could provide variable flow desired. A gate on the outlet of the reservoir would allow water to be metered into the pipeline to the Sheyenne River. The level of water in the reservoir would be maintained within a set range by cycling the pumps in the pump station off and on. The estimated cost for this alternative is shown in Table 5-3. This cost estimate incorporates the more efficiently sized pump station with a control reservoir.

480 cfs Unconstrained Flow

In 1999, analysis of the rising lake indicated that a 480-cfs outlet operating without water quality or channel capacity constraints would be needed in order to stabilize the lake at elevation 1447, if precipitation continued at the rate it had been for the previous 7 years. Therefore, an alternative outlet out of West Bay has been developed with this outlet capacity. No new design was conducted for this outlet versus the 300-cfs constrained flow outlet. Approximate costs shown in Table 5-3 were determined by increasing the costs estimated for the 300-cfs flow pump station by a ratio of the outlet capacity.

Pelican Lake Outlet

The largest inflows into Devils Lake come from Big Coulee and enter Devils Lake through Pelican Lake, which is on the north side of the West Bay. Water quality in Big Coulee is similar to that in the Sheyenne River, making Pelican Lake water much fresher than the rest of Devils Lake, particularly after high runoff events. Therefore, an outlet that withdraws water from Pelican Lake seems attractive because it is the freshest water available in Devils Lake. This could allow the outlet to be more effective in drawing down the lake with flows constrained for water quality than could be expected at other outlet locations. It could also have the least impacts on the Sheyenne and Red Rivers.

This intake location was briefly considered in a 1988 U.S. Army Corps of Engineers feasibility study. More serious consideration and conceptual designs for an outlet from Pelican Lake were investigated in the winter of 1999, after it was found that the effectiveness of constrained-flow West Bay outlets was less than desired.

Several alternatives from Pelican Lake have been considered for the current study. The basic method of transferring water from Pelican Lake to the Sheyenne River is the same for all of the alternatives. The distance between a potential inlet on Pelican Lake and the Sheyenne River is a little over 22 miles. The water must be transported south across the flat Devils Lake basin and then up and over the divide to the Sheyenne River. Peterson Coulee lies within the direct route and would be used similarly to the West Bay outlet alternative. The differences in the plans are in the way that Pelican Lake is separated from the rest of Devils Lake and used to provide fresher water for the outlet. In some of the alternatives, Pelican Lake is considered as just another bay in Devils Lake. In other alternatives, water in Pelican Lake is completely separated from the rest of Devils Lake so that inflow down Big Coulee is effectively rerouted directly to the Sheyenne River. In addition, the goals for water quality on the Sheyenne and Red Rivers differ between alternatives. The common features of the Pelican Lake outlet are described in the following paragraphs.

Based on the 1999 conceptual studies, the first step in withdrawing water from Pelican Lake would be along a 6.1-mile-long open channel from Pelican Lake to a pump station located on the north side of Minnewaukan. The channel would run from Pelican Lake through low ground and then cross Highway 281. It then would follow Highway 281 to the north side of Minnewaukan. Much of this alignment is currently under water. Portions of the existing ground along the proposed channel alignment are at or below elevation 1435 feet msl and wide enough that excavation would not be required.

From the end of the channel on the north side of Minnewaukan, water would be pumped through a pipeline about 16.1 miles long to the Sheyenne River. Initial design work indicated that about 24,000 feet of the pipeline would be ductile iron or steel pipe and the remainder would be reinforced concrete. The pump station and pipeline would be similar to that required for the West Bay outlet through Peterson Coulee, but would have higher design pressures because of the longer length of the pipeline. A control reservoir near the watershed divide would be used to regulate discharge to the gravity flow pipeline. This reservoir is assumed to be approximately 300 feet by 300 feet with perimeter embankment. The pipeline used for the outlet is not designed to accommodate reverse flow.

As an alternate configuration, the West Bay outlet could be constructed and Pelican Lake water could be brought to this pump station. Initial indications from concepts studied in 1999 were that this would be significantly more costly than the concept presented above. A more detailed analysis of outlet routes performed by Barr Engineering in late 2001 confirmed this. The preferred Pelican Lake outlet is therefore as described here.

More fresh water would be available from Big Coulee into Pelican Lake if the historical drainage route from Dry Lake to Big Coulee were restored. Drainage from Dry Lake was diverted directly to Devils Lake through Channel A in 1979. A new channel could be constructed on the northwest side of Dry Lake to allow it to drain to the chain of lakes that flow into Big Coulee. The control structure at the head of Channel A would be used to control flows out of Dry Lake in both the new channel and the existing channel. The initial assumption for operations is that the Channel A control structure would be closed to divert outflow from Dry Lake to Big Coulee as long as the flow rate in Big Coulee is less than 2,000 cfs. If the flow in Big Coulee exceeded 2,000 cfs, the Channel A control structure would be opened enough to allow excess discharge from Dry Lake to flow directly through Channel A to Devils Lake. The operation plan will be refined as design of the outlet progresses. The adequacy of the existing Channel A control structure to perform this operation plan will also be verified in further design. The Dry Lake Diversion feature is included in all of the Pelican Lake alternatives that were analyzed.

Pelican Lake Alternative PL-1

For Pelican Lake Alternative PL-1, the Pelican Lake area is considered as essentially just another bay of Devils Lake. However, the Highways 19 and 281 embankments would separate Pelican Lake water from the rest of Devils Lake so that water can only flow between these areas through the channel under the bridge on Highway 19. The existing culverts under Highway 281 and County Road 19 would be plugged. Under periods of high precipitation, fresh water from Big Coulee would fill Pelican Lake and better quality water would be available to pump to the Sheyenne River. Under periods of low precipitation, drawing water out of Pelican Lake would result in inflow to the area from Devils Lake and a worsening of the quality of water available to pump to the Sheyenne River.

In response to Devils Lake rises to date, Highways 281 and 19 have been raised to minimum elevations of 1451.5 and 1455, respectively. The road embankments could be raised as the lake level rose in order to continue to separate the bodies of water. Cost estimates for the embankment raises have been developed and incorporated into the economic analysis. A tieback levee would be needed along the section road on the north side of Minnewaukan from Highway 281 to high ground. For this alternative, two outlets were considered:

300 cfs Constrained Flow: For this outlet, the pumping rate would be constrained by the 450-mg/l sulfate concentration standard for the Sheyenne River and the nominal Sheyenne River channel capacity of 600 cfs. Costs for the 300-cfs constrained flow outlet from Pelican Lake were developed where possible by using the costs developed for the West Bay outlet and ratioing them by the lengths and sizes required for the Pelican Lake outlet. New cost estimates were developed for features unique to this plan such as the inlet channel from Pelican Lake to the pump station, the control structures under the highway embankments, and any embankments that are needed.

480 cfs Unconstrained Flow: A 480-cfs unconstrained flow outlet from Pelican Lake would be more effective in drawing down lake levels than a 300-cfs constrained flow outlet. In addition, it could be able to discharge better quality water into the Sheyenne River than an unconstrained flow outlet from the West Bay, except in dry periods when there was little inflow into Pelican Lake. Costs for a 480-cfs outlet were developed by using a ratio of the costs estimated for the 300-cfs unconstrained flow outlet, where appropriate. Costs for some of the features, such as the embankment raises and the channel from Dry Lake to Chain of Lakes, are independent of the outlet capacity.

Pelican Lake Alternative PL-2

For Pelican Lake Alternative PL-2, Pelican Lake and the area upstream of it would be completely separated from the rest of Devils Lake along the Highways 19 and 281 embankments. The upstream area would then be continually pumped down and subsequently refilled by inflow from Big Coulee, creating a direct (although limited) connection from Big Coulee to the Sheyenne River. For alternative PL-2, it was assumed that the Pelican Lake area could be pumped down as low as elevation 1441.4 and allowed to fill up to a level equal to the rest of Devils Lake. When inflows caused the level in Pelican Lake to rise to the level of Devils Lake, excess water would then be allowed to flow into the West Bay of Devils Lake to prevent additional flood damages in the Pelican Lake area. The level in the Pelican Lake area would then depend on the amount that can be pumped, the amount of inflow, and the level of Devils Lake. The amount that could be pumped would be determined by the amount of inflow, the pumping capacity of the pump station, and water quality and quantity constraints on the Sheyenne River. The pump station capacity for this alternative has been set at 480 cfs in order to be able to discharge as much as possible to be effective in reducing lake levels.

A control structure would be needed where Highway 19 crosses Big Coulee below Pelican Lake to control flow between the area north of Highway 19 and the West Bay of Devils Lake. As presently conceived, the structure would be on the east side of the existing bridge crossing on the centerline of the existing highway. The structure would consist of an earth embankment to block the coulee and would use a gate well and concrete pipes to control flow through the structure. Under most conditions, the gates would be closed and the structure would separate Pelican Lake and the West Bay of Devils Lake. When inflows raised the level of Pelican Lake to the level of Devils Lake, the gates would be opened to allow excess water to flow into Devils Lake until the inflows subsided to the pumping capacity of the outlet.

For this alternative, it was assumed that the pumping rate would be constrained by a limit of 250 mg/l for sulfate concentration in the Sheyenne River and the nominal Sheyenne River channel capacity of 600 cfs. The 250-mg/l target for sulfate concentration in the Sheyenne River was chosen in order to provide an outlet that would have very minimal effects on the water quality in the Sheyenne and Red Rivers compared to existing conditions, rather than just meeting the standard for sulfate in the Sheyenne River as was done for the PL-1 and West Bay 300-cfs constrained flow alternatives.

Under this plan, the head across the embankments separating the Pelican Lake area from the West Bay of Devils Lake could be 10 feet or more if levels in Devils Lake were to increase and the Pelican Lake area was pumped down to 1441.4. The embankments separating the two areas would then function as dams. The existing road embankments were not designed as dams and have not been constructed to standards expected of dam embankments. For this reason, this alternative would be expected to require a significant amount of work to develop a safe dam embankment between the two areas. The existing road embankments could perhaps be upgraded to accomplish this, but for this planning report it was assumed that a new dam embankment would be constructed north of Highway 19 and west of Highway 281 between Highway 19 and Minnewaukan. A cofferdam would first need to be constructed, and the area between it and the road could be dewatered under controlled conditions to construct the new dam embankment. As currently conceived, the dam embankment would be constructed with a top elevation of 1457 feet msl and be able to safely withstand a lake elevation of 1454 feet msl with 3 feet of freeboard.

Costs for the outlet portions of the alternative are the same as for PL-1. However, costs have been added for the Highway 19 control structure and for the embankments along Highways 281 and 19. The inlet channel costs shown for PL-2 differ slightly from PL-1 due to slightly different assumptions in the depth required for the inlet channel.

Pelican Lake Alternative PL-3

The Pelican Lake alternative PL-3 is very similar to the PL-2 alternative. The difference is that this plan allows inflow to be stored on the Pelican Lake side of the embankments as high as elevation 1454 feet msl, regardless of the level of Devils Lake. If Pelican Lake rises to 1454 feet msl, any excess inflow would then be discharged into Devils Lake through the Highway 19 control structure. Operating with a storage pool up to elevation 1454 feet msl would allow for more storage of fresh water and a greater ability to reduce the level of Devils Lake. However, it would require flooding of lands that otherwise would not be flooded.

The only changes from PL-2 are the additional costs for the higher storage pool. The additional costs are for land easements, rural structure relocations, and raising of affected roads and railroads to protect against water levels of elevation 1454 feet msl or greater upstream of Highway 19.

East Devils Lake Outlet

An outlet could be constructed from East Devils Lake that would require the least amount of construction of any outlet plan. The channel could follow existing low ground to and around Stump Lake and then across the natural outlet and down Tolna Coulee to the Sheyenne River. The divide elevation between West Stump Lake and Tolna Coulee is just 1459, making gravity flow outlets out of this end of the basin possible. There is another natural outlet that flows southwest from East Devils Lake and then bends around to the southeast where it becomes Tolna Coulee. The maximum elevation over this route is just 1465, but the minimum ground elevation is over 1460 for over a mile, requiring much more excavation for an outlet than the route along Stump Lake.

Water quality is much worse in East Devils Lake than in the western part of the lake. Outlets from the east end of Devils Lake designed and operated to constrain discharges to meet water quality standards on the Sheyenne River are not at all effective in reducing Devils Lake levels. The East End outlet alternative has therefore been conceived to operate with flows unconstrained by water quality in the Sheyenne River.

Because of the poor water quality, outlet alternatives from the east end of the lake have not been developed beyond conceptual levels in the past. An outlet alternative from this end of the lake is now being considered because, if operated in an unconstrained manner, it: 1) would have the lowest first cost and operating cost of any outlet; 2) would be as effective as other unconstrained flow alternatives in controlling further rises in lake levels; 3) would minimize impacts to the U.S. Fish and Wildlife Refuge and other land around Stump Lake; 4) would provide an economic basis for quantifying the additional cost for releasing better water quality by selecting alternatives from locations in the western part of the lake; and 5) is preferred by inhabitants around the lake because it would enhance the water quality in the entire Devils Lake, which they hope will result in the creation of a recreational resource for the region.

For this alternative, the outlet from the east end of Devils Lake would be a grass-lined gravity flow channel that initially would follow the natural overflow channel along Jerusalem Coulee between Devils Lake and Stump Lake. At Stump Lake, the channel would be constructed along the west side of the lake until it reached the natural outlet from Stump Lake, which is in an existing channel that obviously formed an outlet for the Devils Lake basin in some historical period. From there, it would continue along the natural Stump Lake outlet route until the channel invert intersected natural ground in Tolna Coulee. From there, Devils Lake water would flow down Tolna Coulee into the Sheyenne River. The excavated portion of the channel is about 16 miles long. The outlet route from Devils Lake to the Sheyenne River is about 28 miles long.

A channel was designed that could allow 480 cfs to flow out of Devils Lake when the lake elevation is 1446 or more. The channel as currently designed has a bottom width of 24 feet, side slopes of 4 on 1, and a bottom slope of 0.00005. The invert at the beginning of the channel would be about elevation 1437 and transitions into Tolna Coulee at about elevation 1432. Most of the channel excavation is 5 to 12 feet deep, but through the Stump Lake natural outlet the required excavation depths are up to 30 feet. Drop structures would be required to control erosion. A drop structure might also be required where the channel transitions into Tolna Coulee because the natural channel is rather steep there.

A gated structure would be needed at a road crossing on the divide between Devils Lake and Stump Lake in order to control outflows to the maximum operating discharge of 480 cfs. However, very large inflows into Devils Lake may exceed the operationally constrained outflow limitations. This would require that excess water be passed into Stump Lake to prevent project-created flood damages around Devils Lake. The gated structure, therefore, would need to be designed to pass excess flows into Stump Lake, as well as control flows into the channel.

The water quality in East Devils Lake is better than in Stump Lake. Therefore, it is desirable to prevent Stump Lake from overflowing into the outlet channel where it skirts the edge of Stump Lake. The current design incorporates features to prevent Stump Lake from inundating the channel even if Stump Lake fills to an elevation of 1459. The channel around Stump Lake follows approximately the 1448 contour, and excavation from the channel would be used to construct an embankment on the Stump Lake side of the channel that would keep channel water separate from Stump Lake water. The design and cost estimate include the use of riprap to prevent erosion of the embankment under high Stump Lake levels.

Raise Natural Outlet

A study objective is to reduce the potential for a natural overflow event and thereby reduce potential damages on the Sheyenne and Red Rivers that a natural overflow would cause. One way of doing this would be to raise the elevation of the natural outlet so that an overflow event would have less chance of occurring. The unfortunate trade-off would be higher potential lake levels in the Devils Lake basin if climatic conditions did result in water elevations that would have spilled over the natural outlet without the outlet raise.

To determine the potential benefits for this alternative, a dam/weir was conceptually designed that would be high enough to prevent overflow due to climatic conditions modeled in the wet scenario. To do this, the crest of the dam/weir is designed at elevation 1463 feet msl. It is conceived that the dam/weir would be constructed as a 380-foot-wide concrete drop structure across the channel that forms the natural outlet. In the event actual conditions are wetter than those represented by the wet scenario, the structure could be overtopped. Therefore, it has been designed to remain intact even if the channel downstream of the weir eroded down to elevation 1450. This is the elevation that has been identified as approximately the lowest elevation down to which the natural overflow might be expected to erode.

The approximate cost for the alternative to raise the natural outlet is shown in Table 5-3. It was analyzed only under the wet future scenario. Costs for the Devils Lake Infrastructure Raise in the table are costs for raising roads, railroads, levees, etc., that would be affected as the lake elevation rose above the natural outlet elevation of 1459 feet msl.

Upper Basin Storage

This alternative examines taking further measures in the upper basin to reduce inflow into the lake by the restoration of “drained” depressions in the 2,616-square-mile upper basin watershed. A vast amount of geographic and historical data was collected to (1) delineate and classify the depressions, and (2) develop a physically based hydrologic model to simulate the hydrologic functions of the depressions.

Depressions in the Upper Basin were delineated and classified as possibly intact, possibly drained, lake, or other based on information obtained from a combination of aerial photos, National Wetlands Inventory (NWI) data, flow direction data, and digital quad maps. The qualifier “possibly” was added to the drainage designation because field verification was not performed during this study. Approximately 294,400 acres of depressions were identified, of which 92,400 acres were identified as possibly drained.

A custom hydrologic model, the Pothole-River Networked Watershed Model (PRINET) was developed to simulate the depression storage, soil storage, and runoff in the Devils Lake basin. This model was developed in order to analyze the effectiveness of reducing runoff into Devils Lake by increasing upper basin storage. The model was calibrated to historic streamflows for water years 1985 through 1999. It was then used to simulate future conditions with and without restoration of drained depressions. Only depressions with a depth equal to or greater than 0.5 foot were considered as candidates for restoration. Eighty-six percent of the surface area of the total possibly drained depression area met this criterion. In the simulation of future conditions, four different levels of restoration were analyzed. These levels represented 25, 50, 75, and 100 percent of the total drained depression volume that could be gained by restoration. For this analysis to determine effects on Devils Lake stage effectiveness and cost-effectiveness, only 50 percent of the possibly drained depressions by volume, with depths greater than 6 in., were used. The assumed 50-percent utilization of the possibly drained depressions is felt to be a reasonable amount of the total drainage that could be acquired and effective in water storage. No effort was made to optimize the most effective depressional areas to be used for storage. (See Appendix A, Section 8, for a more detailed explanation.)

The amount of storage carry-over varies from year to year depending on the depression surface area and evaporation rate. Generally, the annual available depression storage is less than the total depression storage. In dry years, the available storage, and the flow reductions resulting from this storage, will be larger than in wet years.

The Upper Basin Management alternative increases the amount of available upper basin storage volume by 63,000 acre-feet, from a “possibly intact” volume of 482,000 acre-feet to 545,000 acre-feet. On the basis of current studies by WEST Consulting, this is estimated to be approximately 50 percent of the total available upper basin storage. Implementation of this alternative would require placement of approximately 39,000 acres of land into an upper basin storage program. Much of this land is currently farmland.

The analysis assumes that the storage is in place when the lake is above elevation 1440. Previous programs have varied from an annual program to one with a 10-year contract. Therefore, it is assumed that an expanded program could involve contract lengths for any duration up to 10 years. Implementation of an upper basin storage program would involve construction of outlet structures, acquisition or leasing of land, and development of an operating plan for outlet structures when the lake recedes. On the basis of these items, it was assumed that the implementation of the storage would cost $1,000 per acre. Therefore, the total project costs are $39,681,000.

Expanded Infrastructure Protection

Portions of some roadways are currently serving as barriers to the rising and expanding waters of Devils Lake. These roads are acting as dams but they were not constructed to function as dams. This presents the possibility of safety concerns for road users and people living in areas protected by the roads. This alternative examines additional infrastructure measures beyond those described in the "without-project" base condition to ensure a safe level of flood protection within the basin for land protected by roads. The "future without-project" base condition considers any land not protected by embankments designed specifically as dams to be effectively lost due to flooding.

The segments of road currently acting as dams include portions of Highways ND 20 and 57 and Bureau of Indian Affairs (BIA) Roads 1, 4, and 5 on the Fort Totten Indian Reservation. The total length of roads acting as dams is currently about 8 miles. The Federal Highway Administration will not allow the use of Federal highway funds for any future work on those highway segments serving as dams unless their safety can be certified. The Code of Federal Regulations, Title 23, part 650, section 115 (23 CFR 650.115) requires that such embankments must have approval from an agency responsible for the safety of dams. The Army Corps of Engineers has certification responsibility for the safety of dams and the St. Paul District, Corps of Engineers cannot certify the existing roads as dams without major modifications that would likely include additional embankment and methods for controlling seepage on the protected side of the road. The roads currently holding back water have a number of concerns including embedded culverts, evidence of seepage, inadequate compaction during construction as raises took place while the roads were under water, and embedded layers of asphalt and aggregate. Conceptual design work has identified the need for major modifications that would likely include additional embankment with a clay core and methods for controlling seepage on the dry side of the existing road.

The Devils Lake Transportation Task Force developed alternatives that could be used as a physical solution to the current safety issue of roadway embankments serving as dams. Each alternative included costs at three water elevations, those being 1447, 1450 (embankment height of 1455), and 1460 (embankment height of 1465). In all alternatives, dams would be built on the "dry" side of the roads, if possible. In areas away from the roads, the dams would be constructed in the dry by building cofferdams and dewatering the site. The basic features for earth dams that have been selected to control under- and through-seepage are the inspection trench, inclined and horizontal sand drains and filter, and an impervious core. In addition, clearing, grubbing, and the inspection trench would identify and cut off any weak or compressible soils, abandoned drain tile, pipes, culverts, or wells, and sand lenses in the foundation. The inspection trench would be filled with compacted embankment fill. The embankment would be constructed of compacted impervious fill.

For the cost estimate used in the economic analysis, a road-as-dams alternative was selected, where perimeter dams would be constructed between high ground to reduce the number of roads that need to be raised and minimize the amount of homes and land inundated by floodwaters. Culverts would be placed through the roads, allowing water pressures to equalize across the road embankments. The cost of the flood protection portion of this work (i.e., highway and bridge raises are assumed to be funded by others) is $17 million for the stochastic analysis, where the 50-percent probability of future lake stages is about elevation 1450 feet msl. For the wet future scenario, where the stage would reach elevation 1460 feet msl, the estimated cost is $61 million. It was assumed that the raise for a lake elevation of 1447 feet msl had already occurred. The costs of interior drainage are not addressed in this cost estimate. Some pumping with portable pumps would be required; however, with numerous ponding areas typically available, the pumping costs are expected to be minimal. Some overexcavation was assumed to remove weak soils where it appears the alignment goes through wetlands. The dams would be situated in the general location of the temporary levees that are now providing protection. Construction cofferdams would be required in some but not all locations because the ground surface along the embankment alignment is sometimes above the existing lake level. The cost estimate reflects those locations that require cofferdams both on the lake side and land side of the dam in order to construct it in the dry.

Combinations

In addition to evaluation of the above alternatives independently, two combinations of these alternatives have been examined to better determine the relative effectiveness and economy of the alternatives.

Combination 1 - Upper Basin Storage and Expanded Infrastructure Protection

This combination combines the Upper Basin Storage alternative with the Expanded Infrastructure Protection alternative. These alternatives are relatively low cost and risk alternatives that do not create project-related impacts on the Sheyenne and Red Rivers.

Combination 2 - Upper Basin Storage, Expanded Infrastructure Protection, and 300-cfs West Bay Outlet

This option combines the alternatives from combination 1 with an outlet alternative. The 300-cfs West Bay outlet was selected to be used in this combination with the in-basin measures because it is the lowest cost of the outlet alternatives from the fresher side of the lake. The assumption in developing this combination was that, by combining several alternatives, the outlet should be less costly and would not require the higher degree of effectiveness of the more expensive outlet alternatives.

Cost Estimates

Table 5-3 shows estimated costs for most of the alternatives used in the economic analysis. The final cost estimates for the alternatives that will be carried forward for the detailed evaluation (pages 5-118 to 5-158) vary from the estimates shown in this table since the final cost estimates (and resulting Benefit-Cost Ratios) are developed with a greater level of detail. Annual costs for both the stochastic future and the wet future scenario are shown because operational costs differ depending on lake elevation and, in the case of the constrained flow outlets, water quantity and quality on the Sheyenne River.

The costs shown for real estate include the cost for lands and the administration costs to purchase right-of-way for construction of the project around Devils Lake. There will also be real estate costs for easements required along the Sheyenne River to compensate landowners for incremental flood damage caused by the project. For the economic analysis, these incremental flood damages were included with project benefits (as negative benefits) rather than as project costs.

The annual Operation and Maintenance (O&M) costs for the stochastic analysis represent average operating costs for the 10,000 traces. The O&M cost for the wet future is the average yearly cost for operation for that one trace. The operation and maintenance costs for the pumped outlets are derived from several factors. One is general O&M for the alternative, assumed to be 1 percent of the construction costs for years when the outlet is operating and 0.5 percent of the construction costs for years when the outlet is idle. For the outlets with pumps, there is also a replacement cost for the pumps after 25 years of operation and a cost for power for the outlet. The annual power costs are determined by the total volume of water pumped per year, the total dynamic head of the pump station, the motor efficiency, and the cost for the electricity. Electric rates used for the analysis are $0.0225 per kilowatt-hour. The total dynamic head is 240 feet for the West Bay pump station and 270 feet for the Pelican Lake pump station.

Annual costs for downstream water treatment (on the Sheyenne and Red Rivers) were determined from the downstream water users model. These costs are the costs for treatment of river water used by communities and industry to the base condition it would have had without the outlet. They were developed from the traces (wet, two moderate traces, and dry) and are averaged over the 50 years of each trace. Treatment costs for the stochastic future were developed from the four traces. In the economic model, the downstream water treatment costs are treated as benefits (negative benefits) rather than costs, but would be part of the project cost if one of the alternatives were constructed. The dry trace was included in the modeling only for defining costs associated with the stochastic future and was not analyzed separately as a future scenario.

For the East End outlet alternative, only the wet future scenario was analyzed for downstream costs. The treatment cost shown for the stochastic analysis was extrapolated from the wet future treatment costs for the West Bay 480-cfs outlet.

EVALUATION OF ALTERNATIVES

General (Effectiveness, Efficiency, Acceptability)

During the preparation of this report, various alternatives were evaluated to determine the highest expected net benefits. Additionally, cost-effectiveness of alternatives was bracketed in terms of a range of scenarios for various assumed future lake stages. Much of this evaluation was based on data and modeling that were already available.

The base condition to which other alternatives were compared for impact assessment is considered the future without a proposed project condition. This alternative assumes that the types of emergency measures currently being pursued in the project area would continue to be implemented as necessary as the lake continues to rise. These emergency measures include such actions as raising the levees protecting the City of Devils Lake and relocating homes if the lake level continues to rise. If technically and economically feasible, they may also include building temporary levees, raising selected roads and railroads (within limits of reasonable safety acceptance), and protecting or relocating utilities. A continuation of the current level of upper basin storage and measures to minimize erosion at the location of a natural overflow were also considered as potential features of the most likely future without the proposed project.

The stochastic analysis identifies that there is about a 9.4-percent probability that the lake will overflow sometime during the next 50 years. Given this probability, the environmental analysis based on the stochastic future assumes it is unlikely that the lake will overflow naturally. The downstream conditions would be determined by forecasting the existing conditions and determining the effects of project alternatives by themselves.

For the portion of the cost-effectiveness evaluation using a scenario approach, it was assumed that the wet cycle continues at the same degree of wetness as occurred in 1993 through 1999 to the point of naturally overflowing into the Sheyenne River. The wet future scenario repeats the climatic and hydrologic conditions for the seven highest inflow years in recent history (1993-1999) for three cycles, causing the lake to overflow. Proposed actions by the State of North Dakota, such as an overflow to Stump Lake and a temporary outlet to the Sheyenne River, were not assumed to be included in the no-action alternative at this time. A permit has been issued for the Stump Lake channel, but the conditions for operation make it quite ineffective. Therefore, it may never be implemented. The State is continuing to pursue a temporary outlet from West Bay, with initial capacity of 100 cfs, and plans to initiate operation in the spring of 2003. The proposed plan is controversial, however, and still has a high level of uncertainty. A sensitivity analysis of including the temporary outlet as part of the base condition has been performed and is described later in this report. If either or both plans are implemented, or appear likely to be implemented, the evaluation of alternatives will be reviewed to determine what measures are needed to complete National Environmental Policy Act (NEPA) requirements with this changed base condition.

To better understand the sensitivity of assumptions used for assessing the likelihood of future lake conditions, alternatives were evaluated in comparison to other base conditions. Areas investigated under the sensitivity portion of alternative evaluation included:

a) No action.
b) A more moderate[1] future lake scenario – maximum elevation of 1455.
c) Even more moderate future lake scenario – maximum elevation of 1450.
d) Erosion of the natural outlet.
e) Proposed temporary outlet as part of future conditions.
f) Sulfate constraints and operational plan
g) Dry Lake Diversion incremental justification

Basis for a Scenario-Based Analysis in Addition to the Stochastic Analysis

The U.S. Water Resources Council (WRC) guidelines specify the use of "expected" annual flood damage. Expected damage accounts for the risk of various magnitudes of flood damage each year, weighing the damage caused by each flood by the probability of occurrences. Accordingly, the National Economic Development (NED) plan will be the flood damage reduction alternative that reasonably maximizes "expected" net benefits. The stochastic analysis for Devils Lake is designed to calculate expected net benefits. The scenario analysis can calculate net benefits for an assumed future but not "expected" net benefits. For this study, the stochastic analysis would, therefore, represent the method that best fits with the procedures used in accordance with Principles and Guidelines for economic evaluation for determination of probability-weighted damages.

The WRC guidelines do not generally specify which model to use. However, because Devils Lake is a terminal lake, previous lake levels will affect lake levels in any given year. Therefore, the set of annual lake levels is not independent, and standard riverine analysis of lake levels cannot be applied. As a result, the U.S. Geological Survey (USGS) developed a stochastic simulation model that can be used to generate future lake levels and water quality of Devils Lake in response to future precipitation, evaporation, surface water inflow, and potential outlet discharges. The simulation model consists of three parts: (1) a statistical time series model for generating future precipitation, evaporation, and inflow for Devils Lake and Stump Lake and future discharges for the Sheyenne River; (2) a water and chemical mass-balance model for generating future volumes and sulfate concentrations in Devils Lake and Stump Lake in response to future precipitation, evaporation, and inflow; and (3) an outlet simulation model for generating daily outlet discharges and sulfate concentrations to meet downstream water quality and

[1] *The terms "more moderate" and "even more moderate" are future scenarios that are relative to the wet future scenario and not to normal conditions.*

water quantity constraints in the Sheyenne River. The USGS simulation model is described in more detail in Appendix A.

An important assumption of the stochastic model is that climate is stationary or time-invariant; that is, climatic conditions in the Devils Lake basin in the "recent" past are representative of climatic conditions during the future project planning period. The climate in the Devils Lake basin changed significantly during the late 1970's, but has remained relatively homogeneous from 1980 to the present. Therefore, the "recent" past is defined as the period 1980-1999. Although it is unknown exactly how long the current wet conditions may persist, or if even wetter conditions may be in store in the future, climate during the next 10 to15 years is likely to be similar to climate during the period 1980-1999.

Climate in the Devils Lake basin may be nonstationary for a variety of reasons, such as the existence of natural climate cycles caused by global ocean and atmospheric circulation patterns or the existence of global warming due to anthropogenic causes. Residents adjacent to a terminal lake such as Devils Lake would be some of the first to experience the impact of a small change in climate.

Even small changes in precipitation or evaporation can have significant synergistic effects on lake level because these changes are integrated over 3,800 square miles. Small changes in precipitation and evaporation are not significant considerations for hydro-meteorological phenomena such as riverine flood peak hydrology. Consequently, WRC guidelines assume climate invariance. However, for a hydroclimatological phenomenon such as a terminal lake, these considerations are very important for assessing lake level frequency because they are also cumulative in their impact and are subject to persistent weather patterns. (See Appendix A for further rationale for using the scenario approach in addition to the stochastic approach.)

Lake Level Forecasting for Stochastic and Scenario-Based Approaches

A major challenge for evaluating alternatives lies in assessing the likelihood of future lake levels. Devils Lake is currently a landlocked lake, so it is more difficult to estimate the frequency of future lake levels than it is for a simpler system, such as a river. Future lake levels are affected by a variety of climatic factors, as well as by the lake level in previous years and the groundwater level. The Economics Analysis evaluated the alternatives using two approaches to defining the future lake levels: a stochastic approach and a wet future scenario approach that is based on recent climatic conditions.

These future lake levels were generated from a lake model created by the USGS. That model created "traces" of future lake levels. Each trace is a 50-year sequence.

Traces of lake levels were first created for the without-project condition. For each alternative that included a project that would affect lake levels (e.g., an outlet, or creation of additional upper basin storage), the model was modified. An additional trace (or set of traces) was then produced to evaluate the effect of the project in lowering lake levels. In this way, every with-project trace (or set of with-project traces) has a companion without-project trace (or set of without-project traces).

Stochastic Analysis

The stochastic analysis determined the likelihood of future lake levels using a large set of possible future lake levels—10,000 traces. The large number of traces was generated as a way of dealing with the uncertainty regarding future lake levels. Because the calculations of the costs and benefits for any alternative depend on the estimate of future lake level frequency, any cost and benefit calculation can be no more reliable than the estimate of these frequencies. The stochastic analysis provides a large number of lake level series varying according to fluctuations regarding future weather patterns. By computing an alternative's costs and benefits for each of the 10,000 traces, and then averaging those costs and benefits, a reasonable expectation of the cost and benefit for the alternative can be determined.

For the stochastic analysis, every set of 10,000 with-project traces has a companion set of 10,000 without-project traces. Because each trace reflects a particular 50-year projected climate future, each of the 50-year traces is different.

The assumed stochastic future is wet relative to 1900 to 1999; however, it may not be considered wet if the 1800s could be included. The USGS and others believe that 1900 to 1940 may be an aberration relative to climate of the last millennium. Compared to the wet future, it is not as wet. Compared to 1950 to 1999, it is wetter; however, not by a significant factor as it included the drought of 1988-1990. The probability of reaching the overflow elevation sometime in the next 15 years increased from 0.019 to 0.05.

The first 15 years of the stochastic traces were generated based on the assumption that climatic conditions would be similar to those experienced during 1980-1999, reflecting the generally wetter conditions that the Devils Lake basin has been experiencing since 1980.[1] For the modeling, these conditions were assumed to persist until at least 2015.[2] After 2015, the simulation model assumes that climatic conditions can be represented by the longer historic period 1950-1999. The average peak lake level resulting from the stochastic analysis was 1451.7 and the median was 1450.1. (See Appendix A for further discussion of the stochastic analysis.)

Wet Future Scenario Analysis

The wet future scenario analysis evaluated one set of 50-year lake levels that is based on very recent climatic conditions for the years 1993-1999. The wet future scenario repeats the climatic and hydrologic conditions for the seven highest inflow years in recent history

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[1] *The USGS identified evidence of non-stationarity in the precipitation record before and after the late 1970's. See Appendix A.*

[2] *This assumption is based on the results of analysis conducted by Dr. Leon Osborne, Regional Weather Information Center, University of North Dakota.*

(1993-1999) for three cycles, causing the lake to overflow. The remaining years of the 50-year cycle were defined assuming climatic and hydrologic conditions similar to 1980 through 1999, and then 1980 through 1990, to complete the 50-year trace.

The wet future trace rises gradually for about 14 years until the natural overflow occurs in year 2014. The lake remains above the natural outlet elevation for about another 11 years. The peak lake level for this scenario occurs in year 19, at an elevation of 1460.6. There is a second peak that occurs near the end of the 50-year period; however, it has a lower peak flood level than the first peak, and no additional overflow occurs. Although the probability that the lake will rise exactly in this way is zero, more than 5 percent of the traces would reach the overflow elevation of 1459 sometime within the next 15 years and 9.4 percent within the next 50 years. This scenario was chosen to represent the class of traces that would reach this overflow elevation for simulation of downstream impacts. An overflow trace from the stochastic model would have sufficed; however, this scenario also depicts a continuation of the recent wet period. The average peak lake level of all the stochastic traces that spill is 1461.1, which is 0.5 foot higher than the peak lake level of the wet scenario.

Sensitivity Analyses

To better understand the sensitivity of assumptions used for future lake conditions, both with and without project, the alternatives were compared to other possible conditions. The conditions compared for sensitivity are described below.

<u>No-Action Protection Strategy</u>

The purpose of this sensitivity analysis is to perform a baseline check on the sensitivity of assumptions made to develop the “Most Likely Future Without-Project” protection strategy. The “No Action” protection strategy analysis assumes that no action whatsoever will be taken within the Devils Lake basin to protect local infrastructure as lake levels continue to rise. Thus, rising lake levels are assumed to result only in damages and there will be no costs associated with responses made to rising water levels such as road raises, levee raises, etc., that would avert damages. This scenario is not intended to represent a possible future. Its main purpose is to provide an upper bound for net benefits to be compared with the results using the “Most Likely Future Without-Project” protection strategy. It also provides a means to check the effectiveness of continuing non-lake level influencing protection strategies, as is explained in the next paragraph.

In addition to the alternatives listed under the section “Description of Alternatives,” an additional “alternative” was analyzed versus the “No Action” protection strategy, “Continued Infrastructure Protection.” The Continued Infrastructure Protection “alternative” is not an alternative in the sense that it is a potential project, but is intended to analyze the cost-effectiveness of carrying out incremental infrastructure protection measures as the lake continues to rise, just as these measures have been performed with rising lake levels in the recent past. The strategies for protection are essentially identical to the "Most Likely Future Without-Project" protection strategy. The Continued Infrastructure Protection "alternative" will also be combined with the upper basin management and with the 300-cfs West Bay outlet alternatives to analyze the cost-effectiveness of these measures versus continuing incremental infrastructure protection.

Moderate Future Scenarios

The wet future scenario assumes continuation of recent weather conditions that are significantly wetter than those that have occurred in the overall recorded climatological history of Devils Lake. To evaluate the assumptions in this scenario versus other possible futures, two other future scenarios with more moderate wetness were analyzed. Both of these scenarios were taken from the 10,000 traces used to perform the stochastic analysis of future lake levels. In one of the traces chosen, Devils Lake reaches a maximum without-project level of 1455 feet msl. In the other trace, the lake reaches a maximum elevation of 1450 feet msl. The term "moderate" is used for these futures as a relationship to the wet future and not to normal conditions.

> 1455 Moderate Future Scenario – This Moderate Future represents those traces that have an average peak lake level of 1455 (approximately 25 percent of the stochastic traces). This moderate future trace was obtained from within the stochastic traces, as a trace that was representative of this category.
>
> 1450 Moderate Future Scenario – This Moderate Future represents those traces that have an average peak lake level of 1450 (approximately 30 percent of the stochastic traces). This moderate future trace was obtained from within the stochastic traces, as a trace that was representative of this category.

Erosion of Natural Outlet

The purpose of this sensitivity analysis is to evaluate the assumption under the "Future Without-Project" that the natural outlet would erode very minimally during an overflow event. This assumption was based on uncertainty regarding the amount of overflow, on how much it would erode, and on the conjecture that State or Federal agencies would protect the natural outlet at its current configuration in the case of a natural overflow. While it is nearly impossible to predict what may actually be implemented because of environmental, political, or social reasons, a sensitivity of this assumption was necessary to define the potential impacts to the economic feasibility of the alternatives. The erosion of the natural outlet was evaluated only for conditions resulting from the wet future scenario.

Proposed Temporary Outlet as Part of Future Conditions

The State's proposed temporary outlet was not included in the modeling and evaluation of alternatives since there was uncertainty of implementation and lack of actual design parameters of the plan were not determined at the time the Corps was preparing this report. There is high probability for delay or suspension of the plan due to possible litigation and permitting issues. Therefore, the Corps is not including this outlet in the future without project conditions analysis.

However, to be responsive to comments regarding the need to consider the temporary outlet as part of the most likely future without project, a sensitivity analysis was performed assuming the temporary outlet is in place and would operate until the lake level is lowered to elevation 1441.4 to be consistent with the modeled permanent outlet plans. Although the actual minimum elevation for a temporary outlet may be only 1445, this refinement should not affect the analysis. Therefore, this sensitivity analysis evaluates the economic feasibility of the Pelican Lake 300-cfs outlet plan, assuming the state's proposed temporary outlet is operational under the without-project conditions.

For this analysis, the without-project condition assumes construction of the SWC temporary outlet only, and the with-project condition assumes construction of the Pelican Lake outlet only. The Pelican Lake outlet was assumed to begin construction immediately and be operational in 2005. The temporary outlet was assumed to be in place and operational until the lake level drops to elevation 1441.4. The outlet would draw water from West Bay and would begin operation at a capacity of 100 cfs by May 2004 and 300 cfs by May 2006. It would be constrained to not exceed 375 mg/l sulfate concentration or 600 cfs flow at the insertion point.

<u>Sulfate Constraints and Operational Plan</u>

A sensitivity analysis was performed to evaluate the changes in stage effectiveness and downstream water quality if the sulfate constraint was reduced from 450 mg/l to as little as 250 mg/l for the Pelican Lake 300-cfs outlet plan. Additional analysis was also conducted to consider operating strategies for the outflow from dams in the Red River Basin in order to reduce the effects of discharge from a Devils Lake outlet on Red River water quality.

<u>Dry Lake Diversion Incremental Justification</u>

The Dry Lake diversion portion of the Pelican Lake outlet is designed to increase the amount of relatively fresh water that is available for pumping through the outlet. The intent is to be able to pump greater quantities of water from the Devils Lake Basin and, thereby, increase the effectiveness of the outlet in lowering lake levels. The purpose of this sensitivity analysis is to analyze the effectiveness of this component of the outlet, both from an economic standpoint and from the standpoint of pure effectiveness in ability to decrease lake levels.

STOCHASTIC EVALUATION

Table 5-4 summarizes key indicators used in the evaluation of the alternatives for the stochastic analysis; namely, cost-effectiveness (both for the assumed likely future base condition and for the "No Action" base condition) and lake stage effectiveness. Water

Table 5-4: Matrix of Alternatives Considering Cost-Effectiveness and Lake Stage Effectiveness – Stochastic Analysis

	Total Costs	Likely Future		No Action	10% Probability
	($million) [1]	Annl.Net Ben.	BCR	BCR	Lake Level [2]
Alternatives within the Basin		($000's)			
Upper Basin Stor.-50% (UBS)	$40	-$1,877	0.29 [3]	0.59 [3]	1458
Expanded Infrastr.Prot. (EIP)	$17	$1,261	2.10	0.27	1458.8
Raise Natural Outlet [4]					
Outlet Alternatives					
West Bay Outlet (300 cfs)	$88	-$4,206	0.28	0.50	1456
(Peterson Coulee)					
West Bay Outlet (480 cfs)	$168	-$11,115	0.01	0.49	1453
(Peterson Coulee)					
Pelican Lake Outlet (300 cfs)	$117	-$4,893	0.37	0.69	1455
Pelican Lake Outlet (480 cfs)	$206	-$12,364	0.10	0.47	1453
Pelican Lake Bypass (480 cfs) - PL2	$227	-$13,071	0.14	0.25	1455
Pelican Lake Bypass (480 cfs) - PL3	$324	-$17,206	0.21	0.38	1455
East End Outlet	$108	-$7,121	0.02	0.75	1453
Combination Alternatives					
Combination 1 (UBS, EIP)	$56	-$586	0.84	0.50	1458
Combin. 2 (UBS, EIP, Peterson/300)	$141	-$5,083	0.46	0.46	1456
Continued Infrastructure Protection	$139			2.57	1458.8
(this is the "likely future" base					
condition, as measured against					
no action)					

Notes:
[1] - Total costs are present worth of all costs, including annual Operation and Maintenance
[2] - With Stochastic future this lake level has a 10% probability of being reached or exceeded. There is a 9.4 percent chance of the lake overtopping.
[3] - Does not include downstream damages
[4] - This alternative was not evaluated with the stochastic analysis.

quality models cannot be used to directly address in-lake or downstream water quality effects in a probabilistic sense, and will be presented only with the scenario-based analysis.

Cost-effectiveness

Economic feasibility, or the determination of excess benefits over costs, is one of several criteria used for screening alternatives. Planning guidance directs that, all things being equal, the plan with the greatest annual expected net benefits be selected for implementation. Other criteria, though, such as social acceptability, environmental impact, technical feasibility, and effectiveness in solving the problem may influence the plan selection process. Two measures of economic feasibility, the benefit-cost ratio and annual net benefits, have been calculated for each alternative and are used to screen alternatives for selection of a plan.

The outlet alternative under the stochastic analysis with the highest benefit-cost ratio (although it is not shown to be economically justified) is the Pelican Lake 300-cfs outlet.

Sensitivity of No-Action Base Condition

This sensitivity analysis performed a check assuming that no additional action would take place to protect infrastructure around the lake during future lake level rises. As noted in the "No Action" column, the "No Action" protection strategy assumption for the stochastic analysis resulted in higher benefit-cost ratios for all alternatives, as compared to the net benefits computed for the most likely base condition. The benefit-cost ratios are all less than 1.0, except for "Continued Infrastructure Protection."

The "Continued Infrastructure Protection" alternative represents implementation of features assumed to take place as the most likely future base condition. This shows that continued incremental flood protection, as has been taking place in the basin as the lake has risen in the past, is cost-effective.

Hydrologic Effectiveness

To evaluate the hydrologic effectiveness of the proposed Devils Lake management measures, a comparison with the existing, without-project condition is necessary. A variety of analyses can be done, but the most pertinent and most applicable characterization for a terminal lake is the lake's elevation frequency. By comparing this relationship for the with- and without- project conditions, the outlet's hydrologic effectiveness can be measured quantitatively.

As shown on Figure 5-6, the without-project (base) condition has about a 0.094 probability of exceeding elevation 1459 in the next 50 years. The two outlet alternatives with 480-cfs operating plans (West Bay and Pelican Lake) reduce that percentage of exceeding elevation 1459 in the next 50 years to slightly higher than 2 percent, with other alternatives having higher percentages of exceedance.

Water Quality Considerations

The water quality models cannot be used to directly address in-lake and downstream water quality effects in a probabilistic sense. It was practical to run the downstream water quality model only for a limited number of traces selected from the 10,000 generated by the stochastic lake model.

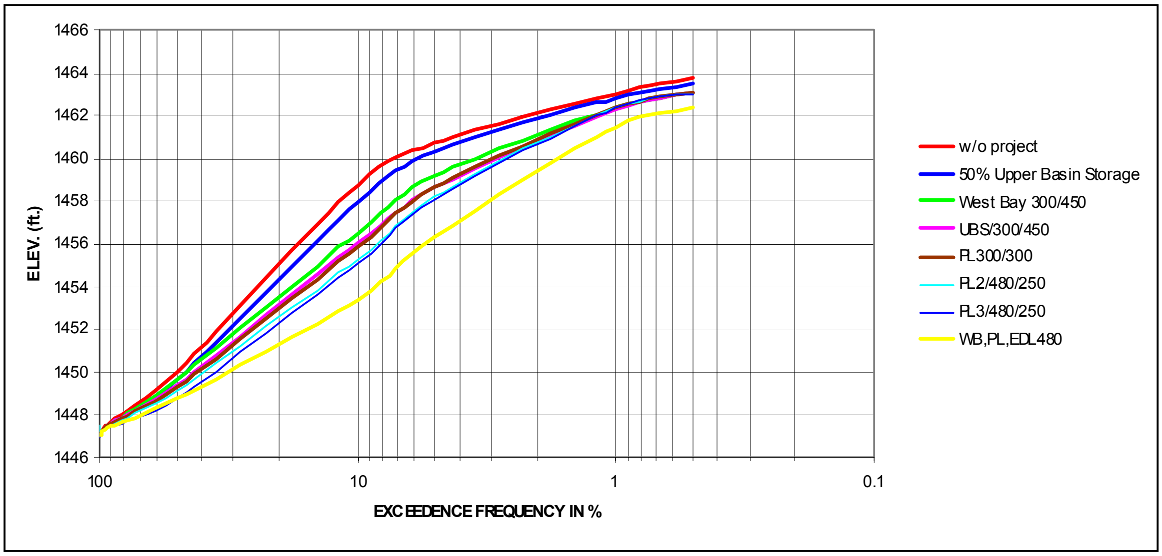

Figure 5-6: Devils Lake: Probability of Exceedance in 50 Years (for the stochastic analysis)

Legend

- *w/o project* – *Base Condition*
- *50% Upper Basin Storage* – *Assumes use of 50 percent of the available depressional area*
- *West Bay 300/450* – *300-cfs outlet from the West Bay with 450-mg/l sulfate constraint*
- *UBS 300/450* – *Combination Plan 2 – Upper Basin Storage, Expanded Infrastructure Protection, 300-cfs outlet from West Bay with 450-mg/l sulfate constraint*
- *Pelican L 300/300* – *300-cfs outlet from Pelican Lake with 300-mg/l sulfate constraint*
- *PL2 480/250* – *480-cfs outlet from Pelican Lake (separated from West Bay) with 250-mg/l sulfate constraint*
- *PL3 480/250* – *480-cfs outlet from Pelican Lake (separated from West Bay and store water higher than natural conditions) with 250-mg/l sulfate constraint*
- *WB, PL, EDL 480* – *Unconstrained 480-cfs outlet from Pelican Lake, West Bay, or East Devils Lake*

Other Environmental Effects

The potential area of impact has been determined from hydrologic, water quality, and groundwater studies associated with the construction and operation of the various alternatives. The potential impact area is based on identified changes in the flow regime, water quality, and groundwater levels.

The impact area in the upper basin is defined as the depression areas identified for restoration. The impact area around Devils Lake is separated by contour zones up to elevation 1463, which is the highest lake level attained if the lake is kept from overflowing naturally to the Sheyenne River under the wet scenario. The impact area on the Sheyenne River is defined by the flooded area outline, area of water quality and flow effects, and area of groundwater influence (¼ mile from the river). The impact area on the Red River is defined by the area of water quality and flow effects and the area of groundwater influence. Although flows and changes in stage would be less on the Red River, the area of potential groundwater influence was still assumed to be about ¼ mile. The environmental effects of the alternatives occur in the upper basin, around Devils Lake, downstream in the Sheyenne River and Red River basins, or a combination depending on the alternative.

The effects of the various alternatives on the major resource areas are summarized in Table 5-5. Both the stochastic and scenario futures are presented in the same table for ease of comparison, as many of the effects are similar, differing primarily in magnitude and duration.

Social Effects

When considering the social effects of a plan to lower the level of Devils Lake, a comparison must be made with the baseline condition and its related social characteristics. The likelihood of future lake levels is difficult to assess and the social effects of a project will vary depending on the assumptions made about the future without a project in place. For instance, the social effects of an outlet will vary considerably depending on the assumption about the potential for overflows from Devils Lake into the Sheyenne River in the future. Social impacts of a project must be evaluated against the future conditions judged as most likely to occur without a project in place.

Upper Basin Storage

On the basis of analyses performed to date, upper basin storage will not meet the project objectives as a stand-alone project. Therefore, it would be more appropriate to consider it as a component of a more comprehensive plan to address the Devils Lake flooding problem. On the basis of hydraulic studies, upper basin storage has only a minor impact in reducing costs and flood damages that otherwise would occur under the without-project condition. This plan, however, is perceived as the solution to the Devils Lake flooding problem by downstream interests, who feel that the lake has been rising in response to increased inflows from the upper basin caused by drainage of wetlands and other depressional runoff storage areas. The downstream interests feel that an outlet and its related water quality and quantity problems should not be imposed upon them until upper basin storage has been tried as a solution to the rising lake problem. Landowners in the upper basin, on the other hand, feel that drainage is necessary in order to productively farm their land. They feel that additional inflows from their drainage practices have had little impact on increasing the lake level.

Table 5-5: Impact Matrix for Devils Lake Study Alternatives

Alternative	Resource				
	Devils Lake Aquatic Resources	**Devils Lake Basin Terrestrial Resources**	**Downstream Terrestrial Resources**	**Downstream Aquatic Resources**	**Biota Transfer**
Existing Conditions	Rise of Devils Lake has benefited fishery. Wetlands have been lost and gained. Significant fishery in lake.	The current lake level has resulted in the loss of over 1 million trees (over 3,000 acres). Terrestrial habitat has been lost and converted to aquatic habitat. 70 Natural Heritage sites located in the basin.	Downstream riparian system and habitat provide good wildlife and natural area values. Riparian land use is predominantly agriculture and natural habitat. Grazing and other water use at the Sheyenne and Red Rivers. 857 Natural Heritage sites located in the Sheyenne basin. 72 in the Red basin.	Sheyenne River and Lake Ashtabula significant aquatic resource. Red River catfish.	Risk of biota transfer due to recreational users and natural causes. Potential for introduction or spread of known and unknown organisms.
Future Without - Stochastic Future	Fishery in lake will continue to improve to a point. Eventually, lake will recede and fishery will decline. Continued construction of levees and roads could affect resources. Infrastructure protection would have little effect on probability of natural overflow and resultant effects. Construction activities would have temporary effect on aquatic habitat such as turbidity. Little long-term effect on fishery.	Wetlands, woodlands, grasslands, and other habitats will be adversely affected as lake fluctuates. Relocation would affect natural resources of the area. Previously developed areas would be reclaimed. Little change from No Action condition, which includes relocations.	No effect downstream if lake does not overflow naturally. Less than 10-percent chance of natural overflow. Therefore, no appreciable change from existing conditions. Infrastructure protection would have no effect on downstream areas.	Not much change expected from current conditions. Less than 10-percent chance of natural overflow. Fishery would maintain itself. Infrastructure protection would have no effect on downstream areas.	Similar to existing conditions. Less than 10-percent chance of natural overflow.
Future Without - Wet Scenario Future	Fishery in lake will continue to improve to a point. Eventually, lake will recede and fishery will decline. Continued construction of levees and roads could affect resources. Infrastructure protection would have little effect on probability of natural overflow and resultant effects. Construction activities would have temporary effect on aquatic habitat such as turbidity. Little long-term effect on fishery.	Wetlands, woodlands, grasslands, and other habitats would be lost as lake rises to overflow elevation. Relocation would affect natural resources of the area. Previously developed areas would be reclaimed. Successional recovery of habitat types as lake recedes. Little change from No Action condition, which includes relocations.	Natural overflow would have significant adverse effect on downstream resources due to increased inundation, erosion, and flows. Infrastructure protection would have no effect on downstream areas.	Significant adverse effect on aquatic resources due to increased flows, water quality changes, and erosion. Some recovery expected once overflow event ends, but recovery could take many decades. Infrastructure protection would have no effect on downstream areas.	Natural overflow would increase potential for transfer of any new or introduced organisms to downstream areas.

West Bay Outlet - 300 cfs	Fresh water removed from lake and lake level lowered, which could affect fishery. Lower lake levels reached sooner than without outlet.	Outlet would lower lake levels about 3 feet. Future inundation of shoreline would be reduced. Lower lake levels would expose shoreline sooner, resulting in quicker successional recovery of terrestrial habitat.	There are 6, 213, and 82 Natural Heritage sites located within 1/4 mile of Upper Sheyenne, Lower Sheyenne, and Red River, respectively. Limited effects due to operation constrained by water quality and channel capacity. Increased groundwater could affect composition of some terrestrial communities. Changes in water quality could have significant effects on aquatic communities.	Release constrained by water quality standards, although increase in levels of constituents. Most effect on aquatic resources in upper Sheyenne due to increased flows. Limited effects due to operation constrained by water quality and channel capacity. Increased groundwater could affect composition of some communities. Changes in water quality and flow could have significant effects on aquatic communities. Most effect on aquatic resources in upper Sheyenne due to increased flows.	Potential for transfer and introduction of new species would increase due to outlet operation. Similar to future without conditions. Potential for spread of Eurasian watermilfoil due to increased flows.
West Bay Outlet - 480 cfs	Outlet would reduce the potential for inundation of new aquatic habitat with resultant effect on fish resource. Outlet would not totally stabilize lake; therefore, some fluctuation in lake levels would continue. Fishery would decline sooner than under future without conditions due to lower lake levels and increased water quality constituent levels. More effect than 300-cfs outlet.	Future inundation of shoreline would be reduced. Lower lake levels would expose shoreline sooner, resulting in quicker successional recovery of terrestrial habitat. Greater effect than 300-cfs outlet.	Similar to West Bay 300-cfs outlet. Significant downstream effects on community structure due to degraded water quality, increased flows, and increased shoreline erosion. 25 Natural Heritage sites located within flooded area of Sheyenne River. Over 600 landowners potentially affected within flooded area outline. Overbank flooding could inundate almost 16,000 acres. Potential loss of riparian vegetation and shoreline vegetation due to inundation and erosion.	Degraded water quality, increased flows, increased erosion, and loss of riparian vegetation. Dramatic change in aquatic communities such as decline in invertebrate, fish, and mussel species, abundance and diversity.	Similar effects as West Bay outlet.
Pelican Lake Outlet - 300 cfs	Fresher and more water is removed from lake than with West Bay outlet, which could affect fishery. Lower lake levels reached sooner than without outlet.	Fresher and more water is removed from lake than with West Bay outlet, which could affect fishery. Lower lake levels would expose shoreline sooner, resulting in quicker successional recovery of terrestrial habitat.	Similar effects as West Bay 300-cfs outlet.	Similar effects as West Bay 300-cfs outlet.	Similar effects as West Bay outlet.

Pelican Lake Outlet - 480 cfs	Fresher and more water is removed from lake than with West Bay outlet, which could affect fishery. Lower lake levels reached sooner than without outlet. In-lake water quality declines due to removing fresh water. Greater effects than with 300-cfs Pelican outlet.	Similar to West Bay 480-cfs outlet. Future inundation of shoreline would be reduced. Lower lake levels would expose shoreline sooner, resulting in quicker successional recovery of terrestrial habitat. Greater effects than with 300-cfs Pelican outlet.	Similar effects as West Bay 480-cfs outlet. Higher flows on Sheyenne River affect riparian vegetation and erosion. More impact than with 300-cfs outlet.	Similar effects as West Bay 480-cfs outlet. Initial flows better water quality but later outlet flows worse due to degraded Devils Lake quality.	Similar effects as West Bay outlet.
Pelican Lake Outlet Only - 300 cfs - No West Bay Flow (PL2 /PL3)	Most of the fresh inflow is removed before it enters Devils Lake. Freshening of Devils Lake is decreased. Fishery could be adversely affected. Lake reaches lower levels sooner and increases in total dissolved solids (TDS) and sulfates over without- project conditions or any other outlet. Upper basin lakes used for storage and subject to increased fluctuation, resulting in decreased aquatic habitat values. Lake Alice National Wildlife Refuge affected, requiring compatibility statement.	Similar to other outlets. Future inundation of shoreline would be reduced. Lower lake levels would expose shoreline sooner, resulting in quicker successional recovery of terrestrial habitat. Upper basin lakes subject to more fluctuation and resulting effects to habitat and wildlife resources. National Wildlife Refuge affected.	There are 6, 213, and 82 Natural Heritage sites located within 1/4 mile of upper Sheyenne, lower Sheyenne, and Red River, respectively. Limited effects due to operation constrained by water quality and channel capacity. Increased groundwater could affect composition of some communities. Changes in water quality could have significant effects on aquatic communities.	Release constrained by water quality standards. Only the freshest water removed from Devils Lake and is similar to Sheyenne base condition. Most effect on aquatic resources in upper Sheyenne due to increased flows. Limited effects due to operation constrained by water quality and channel capacity. Increased groundwater could affect composition of some communities. Changes in water quality could have significant effects on aquatic communities. Most effect on aquatic resources in upper Sheyenne due to increased flows.	Similar effects as West Bay outlet.
East Devils Lake Outlet - 480 cfs	Water quality in Devils Lake improved. Effect on fishery depends on amount of natural reproduction. Could affect population dynamics in the lakes. For example, may result in fewer big fish and more small fish.	Future inundation of shoreline would be reduced. Lower lake levels would expose shoreline sooner, resulting in quicker successional recovery of terrestrial habitat.	Similar impacts to West End 480-cfs outlet.	Increased water quality effects over West end outlets. Upper Sheyenne most affected. Mussels affected by increased chloride levels. Loss of streambank cover and increased erosion have an adverse effect on habitat and fishery.	Similar effects as West Bay outlet.

Raise Natural Outlet	Fishery in lake will continue to improve to a point. Eventually, lake will recede and fishery will decline. Continued construction of levees and roads could affect resources.	Wetlands, woodlands, grasslands, and other habitats adversely affected as lake fluctuates. Greater effects than with future without- project conditions due to additional lands inundated. Greater effects than the future without-project conditions due to additional lands inundated.	No effect downstream. Not much change from existing conditions.	Not much change expected from current conditions. Fishery will maintain itself.	Similar to future without conditions.
Upper Basin Storage	Upper basin storage would reduce runoff to lake, resulting in lake levels about 1 foot lower. Some fresher water would be retained in the upper basin. Probably minimal effect on fishery.	Upper basin storage would reduce runoff to lake, resulting in lake levels about 1 foot lower. Some fresher water would be retained in upper basin. Would prevent inundation of some land areas and loss of habitat. Would modify land uses at storage sites.	Similar to future without conditions.	Similar to future without conditions.	Similar to future without conditions.
Expanded Infrastructure Protection	Would not affect probability of natural overflow and resultant effects. Construction activities would have temporary effect on aquatic habitat such as turbidity. Little long-term effect on fishery.	Relocation would affect natural resources of the area. Previously developed areas would be reclaimed. Little change from "No Action" condition, which includes relocations.	Similar to future without conditions.	Similar to future without conditions.	Similar to future without conditions.

On the basis of previous attempts to voluntarily acquire runoff storage areas in the upper basin, this plan will be difficult and costly to implement. The value of payments to acquire easements for storage areas, which are based on lost productivity of the land, is likely to be contested by landowners. This increases the administrative costs of implementing this plan significantly.

Another possible impact of this plan would be the change in land use in the upper basin area. Converting 30,000 to 40,000 acres of farmland to runoff storage areas reduces the economic base of the local economy that is already highly dependent on the agricultural sector. The storage areas could be farmed in dry years. But, in those years when they could not be farmed, the impact would be felt throughout the local economy.

300-cfs Outlets

A 300-cfs outlet would have a beneficial impact in reducing flood prevention costs and residual flood damage compared to the without-project condition. Associated with this is the beneficial impact of fewer relocations of residential and business properties. Of the different outlet plans evaluated, the Pelican Lake outlet would have the greatest beneficial impact since its higher quality water would allow a greater volume to be released from Devils Lake. The East End outlet would have the lowest beneficial impact as it releases water of the poorest quality. The West Bay outlet would have moderate impacts.

An intangible benefit of the outlet would be the initial psychological boost to the local economy resulting from the perception that the solution to the problem is at hand and that the Devils Lake community will prosper in the future as a result. However, although a 300-cfs outlet would reduce peak lake levels under most climatic conditions, it would not prevent the lake from rising altogether if it is already on an upward trend and most of the costs and damages occurring under the without-project condition would be incurred with this plan in place as well. A 300-cfs outlet may generate controversy among the local community, as the elation initially produced by the outlet is followed by the disappointment of unmet expectations regarding the outlet's effectiveness in lowering lake levels.

Downstream interests may strongly oppose an outlet. This opposition has led to conflict with upstream neighbors who feel unfairly burdened by the lake flooding problem. However, due to the constrained operation of a 300-cfs outlet, actual impacts in terms of increased flood potential or diminished water quality would be less than an unconstrained operation plan, and opposition may moderate over time. In addition, although the plan would not keep the lake from rising altogether, it would drain a sufficient volume of water from Devils Lake to prevent a natural overflow under the wet scenario used in this analysis, another benefit to the downstream community.

Costs are a major concern of the local community. Operation and maintenance (O&M) costs, typically borne by the local sponsor, range from moderate to very high, depending on the outlet alternative. O&M costs for the west end outlets, which require pumping, range from $0.5 to $1.2 million per year. O&M cost estimates for an east end outlet were only developed for a 480-cfs outlet. A proportional estimate for a 300-cfs outlet indicates that the O&M costs would be approximately $30,000 per year. This is one reason why the East End outlet is a locally preferred alternative. Depending on the direction of the lake level in the future, there is the possibility that, once the outlet is built and the lake level drops, the outlet may not be operated.

480-cfs Outlets

A 480-cfs outlet operated in an unconstrained manner would have the greatest beneficial impact in terms of damage reduction around the lake among the alternatives considered. In a number of conditions, it would essentially prevent the lake from rising once it begins operating. Confidence and optimism about the future of the Devils Lake area would be restored and may serve as a catalyst for community growth. At a minimum, a sense of relief and normalcy could return to the Devils Lake community.

Downstream interests would bear most of the negative impacts of this plan. Flooding may increase, primarily on agricultural land along the Sheyenne River. Higher flows may exacerbate streambank erosion that may threaten farmstead structures and residences along the river. The added flow translates into stage increases, resulting in additional damage to structural property from direct flooding. Under these circumstances, flood easements would be purchased to compensate landowners for future expected losses to their properties. The potential for bearing these adverse impacts of an outlet is a source of controversy with downstream interests and has produced conflict with their upstream neighbors.

As with the 300-cfs outlets, costs for the 480-cfs outlets are a major concern of the local community. O&M costs for the 480-cfs East End outlet, which includes a gravity outlet, are estimated to be $35,000 annually, while those for the west end outlets range from $0.8 to $2.0 million per year. This, again, is one reason why the East End outlet is a locally preferred alternative.

The most significant adverse impact would be impaired water quality and the related social and environmental ramifications. Costs would increase significantly to either treat the river water or obtain a supply of water from another source. Those with a strong attachment to the river would undoubtedly experience a sense of loss due to the environmental degradation of the river.

Expanded Infrastructure Protection

This plan has relatively minor beneficial impacts associated with it. These involve some saving of road raise costs and reduction of flood damage to lands and other properties compared with the without-project condition. However, because of the minor flood damage reduction potential of this plan, the Devils Lake area residents would view this plan as an ineffective solution to their flooding problem.

Raise Natural Outlet

By preventing a natural overflow, this plan would raise the lake level higher than the without-project condition for any future condition when the lake reaches elevation 1459 or higher. By inducing flooding above what would occur under the without-project condition, this plan would impose an additional burden upon the Devils Lake region and would meet strong opposition from the local community. The plan would induce additional damage for which landowners adjacent to the lake would have to be compensated. Additional costs for raising roads and dikes and other damage reduction measures would also be incurred. That this project would be implemented to prevent a natural overflow and benefit downstream interests at the expense of Devils Lake residents may cause divisiveness between the two areas.

Cultural Effects

Since the probability of a natural overflow to the Sheyenne River is relatively low (less than 10 percent), a natural overflow is not assumed to be part of the most likely future. Given this, erosion of archeological sites along the Sheyenne River will continue as at present. Cultural resources sites on the shorelines of Devils Lake below elevation 1447 feet have already been inundated or otherwise adversely affected by the prolonged flooding, and this will continue until the lake level drops. Sites on the Devils Lake shoreline at whatever level the lake is at would potentially be subject to wave-caused erosion. Sites along the shoreline of Stump Lakes will be inundated and/or eroded if the overflow from East Devils Lake continues.

SCENARIO-BASED ANALYSIS – WET FUTURE

As discussed earlier, besides the stochastic analysis, alternatives were also evaluated with a scenario-based analysis (with initial evaluation based on a wet future and two other sensitivity evaluations based on more moderate futures). The wet future results are based on a trace that repeats the climatic and hydrologic conditions for the seven highest inflow years in recent history (1993-1999) for three cycles and then assumes climatic and hydrologic conditions similar to 1980-1999 and then 1980 to 1990 to complete a 50-year period. The more moderate future scenarios are based on a representative trace (of the set of 10,000) that reaches the defined lake levels (1455 and 1450).

Since the scenario-based approach does not consider probabilities of future flooding events, this approach to economic analysis has limited application to the alternatives screening process. This approach can provide information regarding the economic consequences of the wet future as defined above for the area around Devils Lake and downstream along the Sheyenne River and Red River of the North. Like the stochastic analysis, the benefit-cost ratio and net benefits have been calculated for each alternative to rank them under the wet future scenario analysis. Based on the assumption of lake level rise and eventual natural overflow intrinsic with the wet future scenario, results from this analysis are different from those of the probability-based analysis.

A cost-effectiveness analysis of alternatives compared against various scenarios of future without-project conditions was used to preliminarily select an alternative for design. Table 5-6 summarizes key indicators used in the evaluation of alternatives; namely, cost-effectiveness, lake stage effectiveness, and downstream water quality impacts.

Cost-effectiveness

With all benefits and costs considered, every alternative appears cost-effective using the wet future scenario approach to the economic analysis, except for the Expanded Infrastructure Protection Plan and the Natural Outlet Raise alternative. Upper Basin Storage and Combination Plan 1, although cost-effective under this scenario, have

Table 5-6: Matrix of Alternatives Considering Cost-Effectiveness, Lake Effectiveness, and Water Quality – Wet Future Scenario

Wet Future Scenario [2]

	Total Costs [1]	Likely Future		No Action	Highest	WQ [3]	WQ [4]	WQ [5]
	($million)	"Annl.Net Ben."	"BCR"	"BCR"	Lake Level			
Alternatives within the Basin		($000's)						
Upper Basin Stor.-50% (UBS)	$40	$541	1.20	1.39	1460	0	4	8
Expand.Infrastr.Prot. (EIP)	$61	$238	1.06	0.10	1460	0	4	8
Raise Natural Outlet	$312	-$3,526	0.83	2.67	1462	0	4	8
Outlet Alternatives								
West Bay Outlet (300 cfs)	$96	$13,341	3.09	2.45	1457	0	27	20
(Peterson Coulee)								
West Bay Outlet (480 cfs)	$183	$16,639	2.37	3.35	1452	3	44	33
(Peterson Coulee)								
Pelican Lake Outlet (300 cfs)	$125	$13,564	2.51	2.47	1457	0	11	12
Pelican Lake Outlet (480 cfs)	$220	$15,530	2.06	2.85	1452	0	21	17
Pel.Lake Bypass (480 cfs) - PL2	$242	$6,132	1.38	1.48	1455	0	7	14
Pel.Lake Bypass (480 cfs) - PL3	$341	$5,051	1.22	1.28	1454	0	8	14
East End Outlet	$148	$18,315	2.85	4.07	1452	58	59	48
Combination Alternatives								
Combination 1 (UBS, EIP)	$97	$822	1.13	0.63	1460	0	4	8
Combin. 2 (UBS, EIP, Peterson/300)	$167	$14,324	2.28	2.14	1456	0	27	20
Continued Infrastr. Protection	$585			1.88	1460	0	4	8
(this is the "likely future" base								
condition, as measured against								
no action)								

Notes:

[1] - Total costs are present worth of all costs, including annual Operation and Maintenance

[2] - There are also economic analyses conducted for more moderate lake levels (1450 and 1455 max. stage), but are not summarized here.

[3] - Downstream water quality, as represented by percentage of time Sulfate standard of 450 mg/L is exceeded at Valley City, ND (years 2005-2014, assuming wet future scenario)

[4] - Downstream water quality, as represented by percentage of time TDS standard of 500 mg/L is exceeded at Halstad, MN (years 2005-2014, assuming wet future scenario)

[5] - Downstream water quality, as represented by percentage of time TDS objective of 500 mg/L is exceeded at Emerson, MB (years 2005-2014, assuming wet future scenario)

[6] - An alternative is evaluated under the wet future scenario approach that was not evaluated under the stochastic approach, the Natural Outlet Raise plan.

[7] - Benefits and costs expressed on an “average annual” basis for a specific scenario assume that the scenario has a 100-percent chance of occurring. This differs from the standard definition of “average annual” which is calculated by assigning probabilities of a range of scenarios as weights in computing expected value of damages, costs, and benefits. Therefore, average annual benefits and costs in scenario context should not be considered the true expected value of benefits and costs for a project.

relatively low benefit-cost ratios (1.20 and 1.13, respectively) and net benefits. The plans with the highest net benefits are the outlet plans. Of these, the 480-cfs plans have higher net benefits than their 300-cfs counterparts. Because of higher costs, though, their benefit-cost ratios are somewhat lower. The plan with the greatest net benefits under the wet future scenario is the East Devils Lake 480-cfs outlet. Again, the results of this analysis of the wet future scenario are significantly different from the results of the stochastic analysis due primarily to the assumed certainty of the lake rising to the overtopping elevation and naturally overflowing into the Sheyenne River.

Sensitivity of No-Action Base Condition

This sensitivity analysis performed a check assuming no additional action would take place to protect infrastructure around the lake during future lake levels. The cost-effectiveness of most of the outlet alternatives goes up slightly with this varied base condition. A notable conclusion may relate to the cost-effectiveness of the infrastructure within the basin. The Continued Infrastructure Protection plan (which is implementation of the most likely future) shows a benefit-cost ratio of 1.88. In comparison of alternatives to a "No Action" base condition, the "Continued Infrastructure Protection" alternative has a positive annual net benefit for both the stochastic and wet future scenario approach. This signifies that the implementation of the Continued Infrastructure Protection within the basin is economically justified, and may in fact represent the most economically defensible approach to flood damage management at the lake. The wetter the future, the more the multiple types of projects are required in the basin to relieve the flooding.

Hydrologic Considerations

The "Highest Lake Level" column of Table 5-6 can be further understood from Figure 5-7, which shows the elevation reduction for each alternative compared with existing conditions for the wet future. The highest lake level for the baseline condition is approximately elevation 1460. The outlet plans that are most effective in reducing the peak lake level for a wet future scenario are those with a 480-cfs unconstrained operating plan, which show a peak lake level of about elevation 1452. This may be further reduced (by approximately ½ foot) if supplemented with an Upper Basin Storage feature.

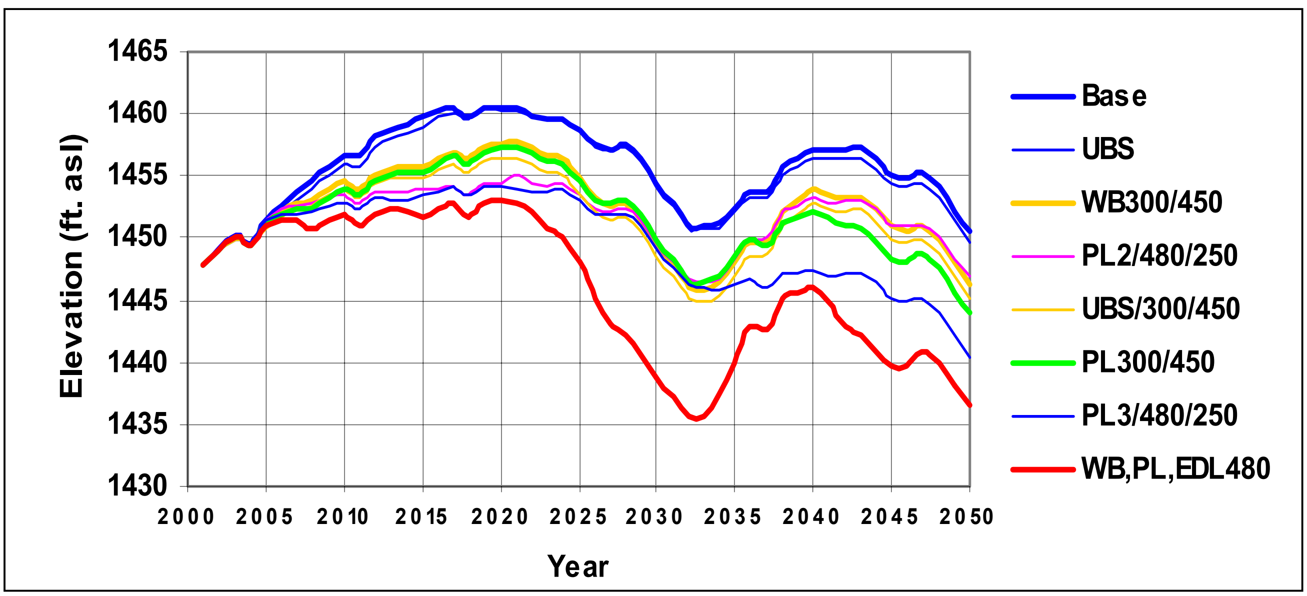

Figure 5-7: Devils Lake Elevation, Wet Future

Water Quality Considerations

The State of North Dakota has classified the Sheyenne River as a Class 1A stream and the Red River as a Class 1 stream, which establishes its designated uses as suitable for aquatic life, boating and swimming, and municipal water supply use subject to treatment by softening to meet chemical drinking water requirements. To protect those designated uses and to evaluate the status of waters with respect to use attainment, North Dakota has established numerical and narrative water quality standards and an antidegradation implementation procedure.

The numerical and narrative standards identify the chemical concentration values or other physical measures or limits that would have to be met pursuant to the Federal Clean Water Act (FCWA) Section 404(b)(1) guidelines, and Section 402 National Pollutant Discharge Elimination System (NPDES) permitting process. Tables 5-7 and 5-8 list the numerical standards applicable to Class 1 and 1A streams.

Table 5-7: State of North Dakota Water Quality Standards for the Red River of the North (Class 1)

Substance/Condition	**Standard**	**Method of Analysis**	**Effect of Outlet, P. Lake, 300 cfs, constrained**
Ammonia (as N)	(Formula, see rules)	Not modeled	No prediction
Barium (Total)		No analysis, No data	
Boron (Total)	0.75 mg/l	Ambient D.L. value <stnd	No exceedance
Chlorides (Total)	100 mg/l	HEC-5Q	**Elevated >15% No exceedance**
Chlorine Residual	0.011 mg/l	Not modeled	No prediction
Dissolved Oxygen	Not <5 mg/l	HEC-5Q	No exceedance
Fecal Coliform	200 per 100 ml	No analysis	No prediction
Nitrates (N)	1.0 mg/l (see rules)	HEC-5Q	**Elevated >15% No exceedance**
pH	7.0 – 9.0	HEC-5Q	No exceedance
Phenols (Total)	0.1 mg/l	No analysis	No prediction
Phosphorus (Total)	0.1 mg/l (see rules)	HEC-5Q	**Elevated >15% No exceedance**
Sodium	50% of Tot. Cations	HEC-5Q	**Elevated >15% No exceedance**
Sulfates (Total)	250 mg/l	HEC-5Q	**Elevated >15% No exceedance**
Temperature	(see rules)	HEC-5Q	No change
Comb. Radium 226/228	(see rules)		No prediction

Gr. alpha particle activity	(see rules)		No prediction

Table 5-8: State of North Dakota Water Quality Standards for the Sheyenne River (Class 1A. All criteria same as for Class 1 except the following)

Substance/Condition	Standard	Method of Analysis	Effect of Outlet, P. Lake, 300 cfs, constrained
Chlorides (Total)	175 mg/l	HEC-5Q	**Elevated >15% No exceedance**
Sodium	60% of Tot. Cations	HEC-5Q	**Elevated >15% No exceedance**
Sulfates (Total)	450 mg/l	HEC-5Q	**Elevated >15% No exceedance**

The antidegradation rule provides for oversight in the case where a new or expanded source of pollutants, even while meeting numerical standards, would cause a significant permanent effect on the quality and beneficial uses of the affected waters. A determination of "significant effect" would be that the ambient quality of any parameter would be degraded by more than 15 percent, or that the available assimilative capacity would be reduced by more than 15 percent, or that any permitted pollutant loading would be increased by 15 percent. The operator of a Devils Lake outlet would be required to obtain an NPDES permit from the North Dakota Department of Health (NDDH). The antidegradation review is an important part of the NPDES permitting process.

Under the FCWA, the NDDH cannot issue an NPDES permit for an activity that causes exceedance of numerical State water quality standards, including the standards of an adjoining or downstream State whose waters would be affected by the activity, without obtaining variances. The NDDH can permit a variance to the water quality standards of an affected segment within its jurisdiction when by reason of substantial and widespread economic and social impacts the strict enforcement of water quality criteria is not feasible. A variance can be granted only after fulfillment of public participation requirements and Environmental Protection Agency (EPA) approval. The EPA has indicated in correspondence that it was confident that the State of North Dakota would ensure that no NPDES permit would be issued if it would cause a violation of North Dakota or Minnesota water quality standards. The EPA has the authority to intervene to ensure compliance with the applicable water quality requirements of all affected states.

The 1909 Boundary Waters Treaty (BWT) provides that "… the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property of the other." (BWT – Article IV) In May 1969, the United States and Canada adopted specific water quality objectives recommended by the International Joint Commission (IJC). The IJC was established by the BWT – Article VII and given jurisdiction by BWT - Article VIII over matters dealing with BWT – Article IV. Those objectives are:

TDS	500 mg/l (maximum)
Sulfate	250 mg/l (maximum)
Chloride	100 mg/l (maximum)
Dissolved oxygen	5.0 mg/l (minimum)
Fecal coliform	200 per 100 ml (maximum)

The Province of Manitoba has a policy to maintain, enhance, and protect the chemical, physical, and biological integrity of all surface waters. Manitoba has formulated surface water quality objectives that define the minimum levels of quality required to protect water uses. The surface water quality objectives are designated concentrations of constituents that, when not exceeded, will protect an organism, a community of organisms, a prescribed water use, or a designated multiple water use with an adequate degree of safety. Manitoba specifies that the objectives would be interpreted as maximum acceptable concentrations not to be exceeded at any time in any place, except where otherwise specified (i.e., low flow conditions, mixing zones). A technical draft of the objectives and guidelines report is available from Manitoba Conservation on the Internet. One of the most prominent emerging issues is eutrophication, especially of Lake Winnipeg. The concerns over eutrophication have prompted an intensive ongoing effort to develop a nutrient management strategy for southern Manitoba. Any activity in the U.S. portion of the Red River of the North basin that would increase the nutrient load to the system would further complicate management initiatives that are already difficult and costly to implement.

Water quality modeling was performed for the continued wet cycle scenario to compute the downstream routing of Devils Lake outlet water affecting water quality and flow in the Sheyenne River, the Lake Ashtabula reservoir, and the Red River of the North from the Sheyenne River confluence to the Canadian boundary at Emerson, Manitoba. The model generated daily flow and concentration data for the 50-year-long operating scenario so that effects at any of several hundred downstream locations could be compared with the no-outlet base condition. The data were used to evaluate the impact of outlet operations with respect to regulatory compliance parameters and nutrients. The data were also used to evaluate mitigation costs in the downstream water users study, potential effects on aquatic life, and potential effects on soil salinity (see other sections). In this section, discussion of downstream water quality effects focuses primarily on sulfate and TDS.

In-Lake Water Quality Effects

Figure 5-8 shows the recent historical and expected changes in levels of TDS in Main Bay of Devils Lake, based on the wet future scenario. Historically, the TDS levels exceeded concentrations of 4,000 mg/l prior to 1992. As the lake level increased more rapidly beginning in 1993, the water freshened to the present concentration of about 1,400 mg/l. With the wet future assumption, the base condition would continue dropping to levels of approximately 1,000 mg/l and then rise to about 1,500 mg/l over the next 50 years. All of the outlet configurations, except the East Devils Lake outlet, cause TDS levels to increase relative to the base condition. Pelican Lake outlet operations would

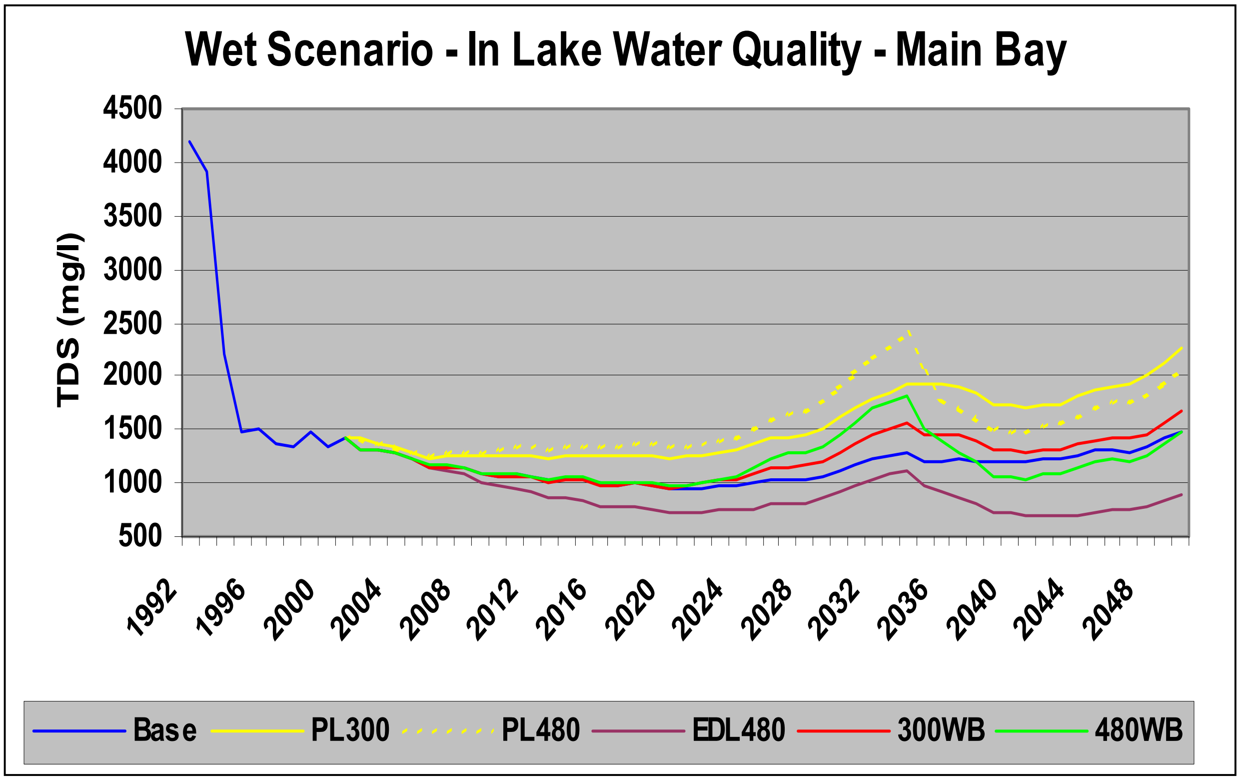

Figure 5-8: TDS Levels in Main Bay of Devils Lake, Wet Future Scenario

cause increases of about 700 mg/l over the baseline; however, these levels are still lower than those prior to 1993. Similar effects would be seen in East Bay and East Devils Lake.

Downstream Water Quality Impacts

The following information about downstream water quality effects refers primarily to expected changes in chemical concentrations relative to North Dakota and Minnesota numerical water quality standards, the IJC boundary waters objectives, and North Dakota antidegradation criteria. It is recognized that all three jurisdictions also employ non-numerical or "narrative" standards that generally provide protection against activities that would in any way substantially degrade designated beneficial uses of the waters. This analysis addresses narrative standards in the context of North Dakota's antidegradation (15-percent change) criteria. Tables 5-7 to 5-10 list the water quality parameters, specific limits, method of analysis, and findings of effect for the Pelican Lake (300-cfs constrained, 450-mg/l sulfate) outlet alternative. The methods of analysis included HEC-5Q model simulations and observation of recent Devils Lake monitoring data. Predictions based on the monitoring data are not quantitative but assert that if maximum concentrations in West Bay of Devils Lake are less than the standards, then outlet operations could not cause exceedances. Several of the parameters were found to exceed the 15-percent antidegradation limit without exceeding the numerical standards. The only

Table 5-9: State of Minnesota Water Quality Standards for the Red River of the North (Class 2A, 1B, 3B)

Substance/Condition	**Standard**	**Method of Analysis**	**Effect of Outlet, P. Lake, 300 cfs, constrained**
Ammonia	None	No analysis	No prediction
Asbestos, fibers	7.0e+06	No analysis	No prediction
Bicarbonates	5 meq/l	No analysis	No prediction
Chloride	100 mg/l	HEC-5Q	No exceedance
Chlorine tot. resid.	38 ug/l	No analysis	No prediction
Color, Pt-Co units	15	No analysis	No prediction
Cyanide, free	45 ug/l	No analysis	No prediction
Fluoride	2 mg/l	No analysis	No prediction
Foaming agents	500 ug/l	No analysis	No prediction
Hardness, as CaCO3	250 mg/l	HEC-5Q	**Elevated >15% Exceedance of Standard**
Nitrate, as N	10 mg/l	No analysis	No prediction
Nitrite, as N	1 mg/l	No analysis	No prediction
Nitrate + Nitrite as N	10 mg/l	HEC-5Q	No exceedance
Odor, TON	3	No analysis	No prediction
Oil	10000 ug/l	No analysis	No prediction
PH	6.0 – 9.0	HEC-5Q	No exceedance
Sulfate	250 mg/l	HEC-5Q	**Elevated >15% No exceedance**
Temperature	No increase	HEC-5Q	No exceedance
Total Dissolved Solids	500 mg/l	HEC-5Q	**Elevated >15% Exceedance of Standard**
Turbidity, NTU units	1-5	No analysis	No prediction
Aluminum	50 – 200 ug/l	Ambient D.L. value <stnd	No exceedance
Antimony	6 ug/l	No data	No prediction
Arsenic	50 ug/l	Ambient D.L. value <stnd	No exceedance
Barium	2000 ug/l	No data	No prediction
Beryllium	4 ug/l	No data	No prediction
Cadmium	5 ug/l	No data	No prediction
Chromium +6	32 ug/l	Ambient D.L. value <stnd	No exceedance
Chromium total	100 ug/l	Ambient D.L. value <stnd	No exceedance
Cobalt	872 ug/l	No data	No prediction

Copper	1000 ug/l	Ambient D.L. value <stnd	No exceedance
Iron	300 ug/l	Ambient D.L. value <stnd	No exceedance
Manganese	50 ug/l	Ambient D.L. value <stnd	No exceedance
Mercury	2 ug/l	USGS Recon. Survey 2001	**INCREASED LOAD**
Nickel	100 ug/l	Ambient D.L. value <stnd	No exceedance
Selenium	40 ug/l	Ambient D.L. value <stnd	No exceedance
Silver	100 ug/l	Ambient D.L. value <stnd	No exceedance
Thallium	2 ug/l	No data	No prediction
Zinc	5000 ug/l	Ambient D.L. value <stnd	No exceedance
Numerous organic substances	See rules	No data	No prediction

Table 5-10: International Joint Commission Boundary Waters Water Quality Objectives, Red River of the North

Substance/Condition	**Objective**	**Method of Analysis**	**Effect of Outlet, P. Lake, 300 cfs, constrained**
Fecal coliform	200 colonies/100 ml	No data	No prediction
Chloride	100 mg/l	HEC-5Q	No Exceedance
Sulfate	250 mg/l	HEC-5Q	No Exceedance
Total Dissolved Solids	500 mg/l	HEC-5Q	**EXCEEDANCE**
Dissolved Oxygen	Not <5 mg/l	HEC-5Q	No Exceedance

numerical standards found to be exceeded were total dissolved solids (TDS) and total hardness on the Red River of the North (Minnesota standards) and TDS for the international objectives. Expanded discussion of selected parameters follows.

Summary of Water Quality Effects

The following summary of the effects of outlet operations under the continued wet cycle describes the downstream effects in terms of the amount of time during the first 10 years of operation that the sulfate or TDS standards would be exceeded. The data cited are from Tables 5-11 through 5-13 and Figures 5-9 through 5-11. More comprehensive concentration exceedance information is presented in Appendix A, including exceedance of concentrations higher and lower than the regulatory limits and for the moderate and dry future scenarios. The 10-year time frame was chosen for the concentration exceedance analysis because it establishes a statistical basis for comparing the effects of all of the

Table 5-11: Water Quality Effects
Sulfate - Percent of Time Exceeding 250 mg/l
During First 10 Years (2005 – 2014)

	Sheyenne River			Red River of the North		
Scenario	**Cooperstown**	**Valley City**	**Kindred**	**Halstad**	**Grand Forks**	**Emerson**
WET BASELINE	8	2	5	0	0	0
Wet 300 PL	14	13	2	0	0	0
Wet 480 PL	29	34	18	0	0	0
Wet 300 WB	57	55	41	0	0	0
Wet 480 WB	60	73	64	1	0	0
Wet 480 EDL	64	84	78	18	2	2

Table 5-12: Water Quality Effects
TDS - Percent of Time Exceeding 500 mg/l
During First 10 Years (2005 – 2014)

	Sheyenne River			Red River of the North		
Scenario	**Cooperstown**	**Valley City**	**Kindred**	**Halstad**	**Grand Forks**	**Emerson**
WET BASELINE	82	52	73	4	0	8
Wet 300 PL	86	77	77	11	0	12
Wet 480 PL	87	84	80	21	0	17
Wet 300 WB	87	88	85	27	1	20
Wet 480 WB	87	90	88	44	8	33
Wet 480 EDL	88	92	91	59	29	48

Table 5-13: Water Quality Effects
Sulfate - Percent of Time Exceeding 450 mg/l
During First 10 Years (2005 – 2014)

	Sheyenne River			Red River of the North		
Scenario	**Cooperstown**	**Valley City**	**Kindred**	**Halstad**	**Grand Forks**	**Emerson**
WET BASELINE	0	0	0	0	0	0
Wet 300 PL	0	0	0	0	0	0
Wet 480 PL	0	0	0	0	0	0
Wet 300 WB	0	0	0	0	0	0
Wet 480 WB	2	3	0	0	0	0
Wet 480 EDL	51	58	34	0	0	0

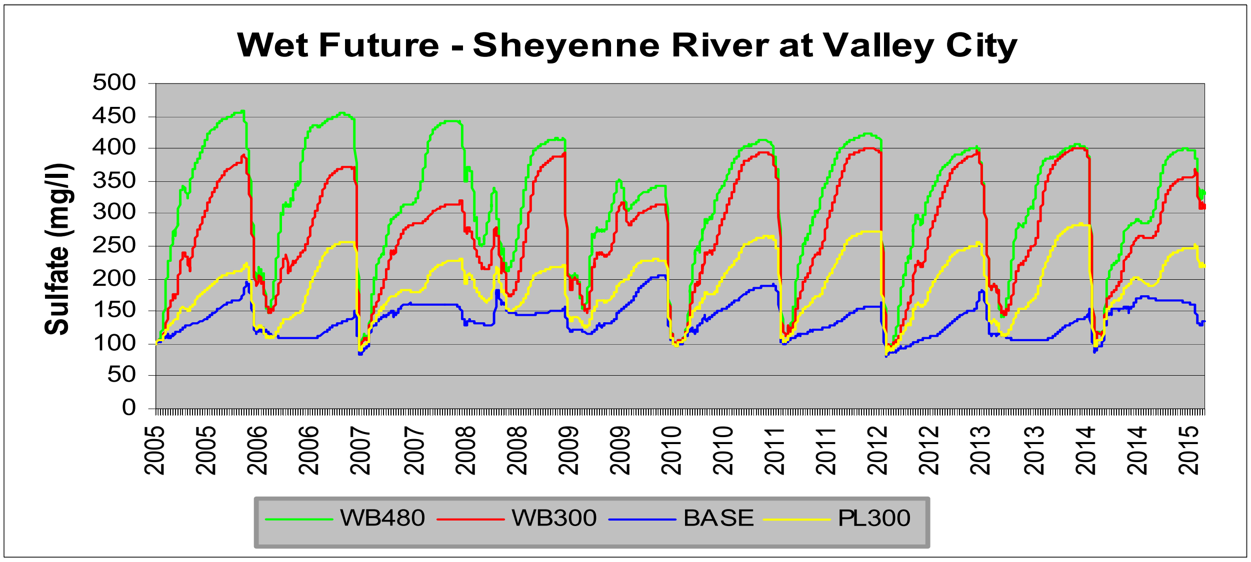

Figure 5-9: Sulfate Effects – Sheyenne River at Valley City, Wet Future

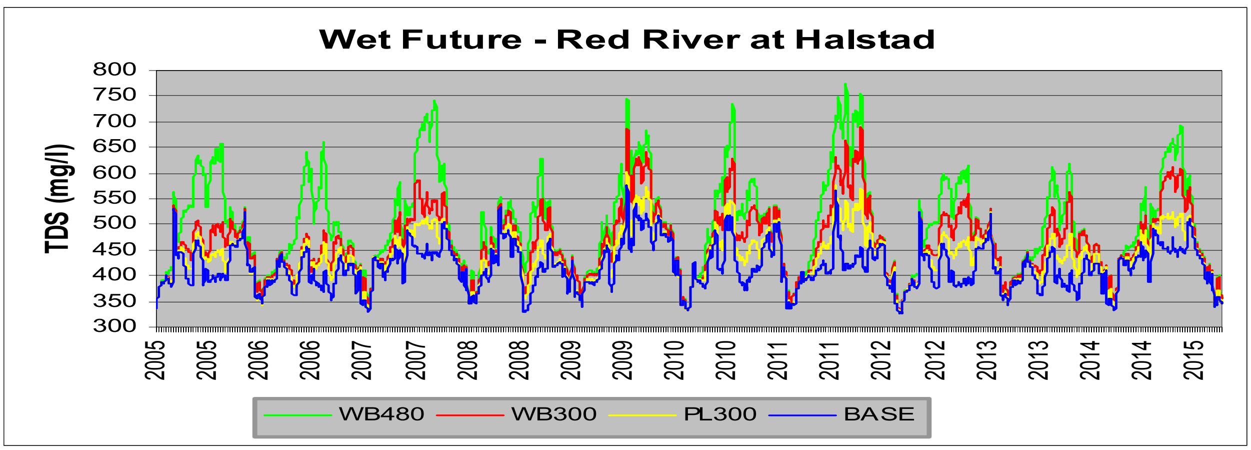

Figure 5-10: TDS Effects – Red River at Halstad, Wet Future

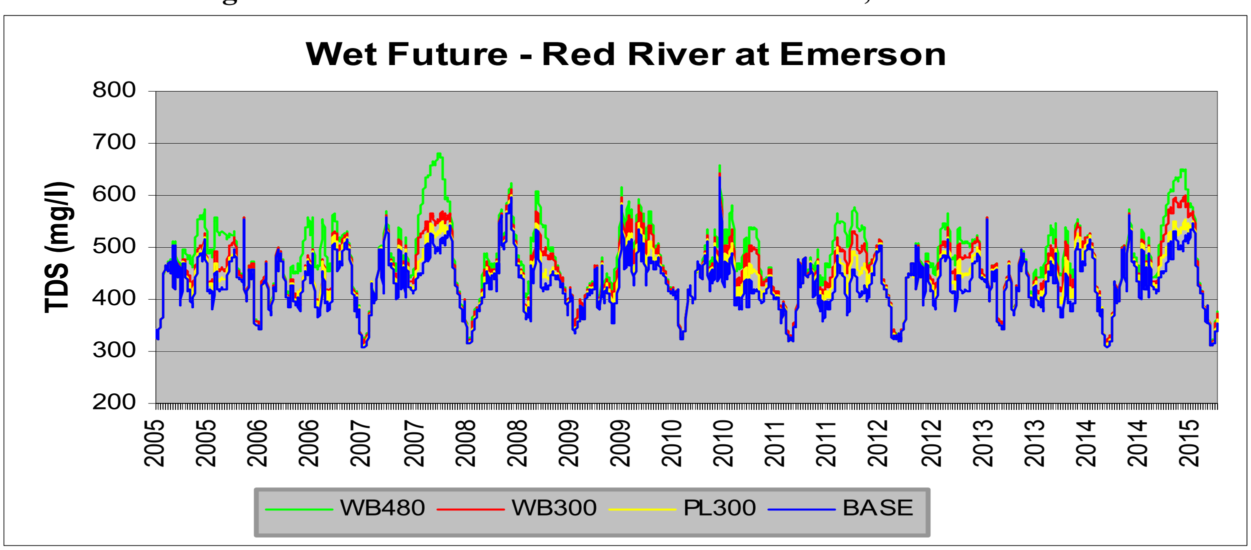

Figure 5-11: TDS Effects – Red River at Emerson, Wet Future

outlet scenarios, including the moderate and dry future scenarios. The effect of the uncontrolled overflow scenario is not included in the tables because the effect of the spill does not occur in the same 10-year time frame.

From the standpoint of the State of North Dakota's antidegradation implementation procedure, a determination of "significant effect" could be made with respect to many chemical parameters whose concentrations would remain well below the limits assigned by the standards even in the most benign operational scenarios. For example, during a typical operational period with a Pelican Lake outlet in the wet scenario, the increase in chloride concentrations would range between 100 percent and 600 percent over the baseline in the upper Sheyenne River without exceeding the standard of 100 mg/l. Similarly, the concentration increase and loading increase of many other parameters could exceed the 15-percent limit established by the antidegradation rules by more than an order of magnitude. Any finding of "significant effect" would trigger a review process at the end of which the North Dakota Department of Health would make a final decision to allow or disallow the water quality change based on a determination of necessity to accommodate important economic or social development. In either case, beneficial uses must be protected.

300 cfs Constrained (450 mg/l sulfate and 600 cfs) – The outlet would operate mostly unconstrained by the sulfate limitation because of the abundance of relatively fresh water at the west end of the lake. The 450-mg/l sulfate standard on the Sheyenne River would not be exceeded, but the ambient concentration would be sustained at levels above 250 mg/l for more than half of the time. With West Bay operations, the TDS standard on the Red River near Halstad, Minnesota, would be exceeded 27 percent of the time (base condition 4 percent). The international objective for TDS would be exceeded 20 percent of the time (base condition 8 percent). With Pelican Lake outlet operations, the sulfate concentration at Valley City would be sustained at or above 250 mg/l 13 percent of the time, the TDS standard on the Red River near Halstad would be exceeded 11 percent of the time, and the international objective for TDS would be exceeded 12 percent of the time.

480 cfs Unconstrained – Operation from West Bay would exceed the North Dakota sulfate standard for the Sheyenne River only 3 percent of the time, but the ambient concentration at Valley City would be sustained at levels above 250 mg/l for more than 70 percent of the time. The TDS standards at Halstad and Emerson would be exceeded 44 percent (4 percent base) and 33 percent (8 percent base) of the time, respectively. Operations from East Devils Lake would cause excess concentrations at Halstad and Emerson for 59 percent and 48 percent of the time, respectively. With Pelican Lake outlet operations, the sulfate concentration at Valley City would be sustained at or above 250 mg/l 34 percent of the time, the TDS standard on the Red River near Halstad would be exceeded 21 percent of the time, and the international objective for TDS would be exceeded 12 percent of the time.

Nutrient Loading Effects

Devils Lake outlet operations would introduce a new source of plant nutrients (phosphorus and nitrogen) into the Sheyenne River and Red River of the North, potentially affecting the productivity and abundance of algae and aquatic plants in downstream environments. The assessment of potential specific nutrient effects from Devils Lake outlet operations is a more complex problem than the assessment of dissolved solids issues for two reasons: 1) nutrients such as phosphorus and nitrogen should not be assumed to be non-reactive; and 2) there is seldom a simple direct relationship between concentration and effect. The nutrient loading effects may also be dependent on other outlet operations physical variables such as increased flow, velocity, reduced travel time, channel erosion, reduced hydraulic residence time (in reservoirs), and turbidity (affecting light penetration necessary for photosynthesis). More sophisticated aquatic models have the capability of integrating these and many other relationships such as primary consumption, competition, predator-prey, and other processes, such as recovery of perturbed or destabilized communities (ecological succession).

The HEC-5Q water quality model of the Sheyenne River and the Red River of the North was used to estimate downstream ambient conditions and loadings of phosphorus based on materials routing that included hydraulic routing. It also included a general representation of the major physical and biological pathways that nutrients travel. For example, the model grows, reproduces, kills, and decomposes planktonic and benthic algae in the rivers and in Lake Ashtabula. It does not, however, directly predict algae blooms or other nuisance aquatic plant problems. Without knowledge of critical site-specific and time-variable conditions, the value of estimated concentration load data is limited, but it may be useful in judging the significance of the relative change. For example, an increase in the concentration of phosphorus was known to be or suspected to be limiting plant growth in the base condition. Similarly, an increase in phosphorus load might be considered significant if a downstream lake or reservoir was known or thought to be experiencing accelerating eutrophication.

With the exceptions of sulfate, TDS, and the associated "conservative" constituents, water quality in Devils Lake was not modeled. For the purpose of loading the HEC-5Q nutrient model, Devils Lake nutrient concentrations and other variables were assigned as constants based on the medians or means of recent monitoring data. Concentrations for total phosphorus and nitrate nitrogen, representing the Devils Lake outlet tributary to the Sheyenne River, are 0.29 mg/l and 0.045 mg/l, respectively. Monitoring data indicate that, unlike TDS and sulfate, these variables behave independently of lake level changes and uniformly throughout the lake chain.

The State of North Dakota water quality standards for class 1 and 1A streams (effective June 2001) identify "interim guideline limits" for total phosphorus and nitrogen subject to unique or site-specific stream characteristics that may contribute to excessive plant growth or eutrophication. The interim guideline for total phosphorus on the Sheyenne River is 0.1 mg/l and for nitrates is 1.0 mg/l. Historic monitoring data indicate that the phosphorus guideline is rarely met and is often exceeded by a large margin. The nitrogen guideline is rarely exceeded.

Under Section 303(d) of the Clean Water Act and its accompanying regulations (40 C.F.R. Section 103.7) each state is required to identify lakes, rivers, and reservoirs that are considered to be water quality limited and require waste load allocation analysis or Total Maximum Daily Load (TMDL) determinations. The State of North Dakota's TMDL list, submitted to the Environmental Protection Agency in April 1998, identified all reaches of the Sheyenne River as use-impaired for aquatic life due to nutrients, sediment, habitat, and bacteria. Lake Ashtabula and the river reach from Baldhill Dam to the Barnes County line were prioritized as "High" and "Targeted" [for TMDL].

In the base condition, HEC-5Q simulation for the upper Sheyenne River (Figure 5-12) interim guideline limit for total phosphorus is exceeded 100 percent of the time. The with-outlet simulation indicates that phosphorus concentrations would be sustained at levels from 10 to 100 percent higher than the baseline condition and generally higher than 0.25 mg/l during operational periods. The increased phosphorus concentration would exceed the North Dakota antidegradation significance threshold of 15 percent, at which the antidegradation review process would generally, but "not necessarily" (according to communication with the North Dakota Department of Health) be invoked.

The simulations indicate that outlet operations would not increase nitrogen concentrations downstream and would sometimes reduce ambient nitrogen (see Appendix A).

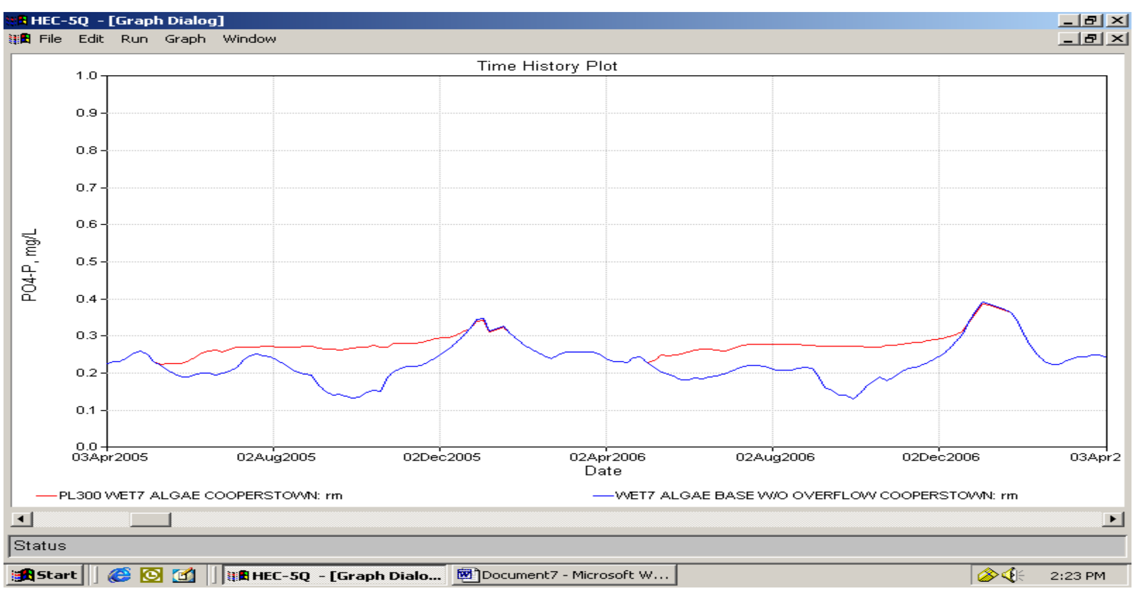

Figure 5-12. Phosphorus Concentrations in Upper Sheyenne River (at Cooperstown) With and Without Pelican Lake 300-cfs Outlet

The annual phosphorus load to Lake Ashtabula would increase by about 40 metric tons per year (Figure 5-13) during the first 10 years of operation, which is variably a 60- to 100-percent increase over the base condition. These numbers could similarly invoke an antidegradation review based on the 15-percent loading threshold, but the issues would be the same for the entire Sheyenne River and would probably not be a separate process. The HEC-5Q model of Lake Ashtabula indicates that there would be very little response of algae to the increased phosphorus load because the lake is already well nourished and the concentration of phosphorus during the summer does not change much. It is important to consider that the very high increased phosphorus load would be accompanied by a proportionately high water load with its attendant assimilative capacity and effective shortening of the summer residence time in the pool. In other words, much of the phosphorus, and whatever plankton it nourished, might not reside long enough in the pool to contribute eutrophication effects.

On the Sheyenne River downstream of Lake Ashtabula, the phosphorus concentration would increase during mid- to late summer and decrease slightly during the winter and spring (Figure 5-14). Some of the variability downstream of Lake Ashtabula would be due to a phase shift of the hydraulic cycle caused by increased flow during the operating season. That is why the with-outlet concentration in the simulations is sometimes less than the base condition and sometimes greater than can be accounted for directly by phosphorus from Devils Lake. Nitrogen concentrations would remain below the base condition.

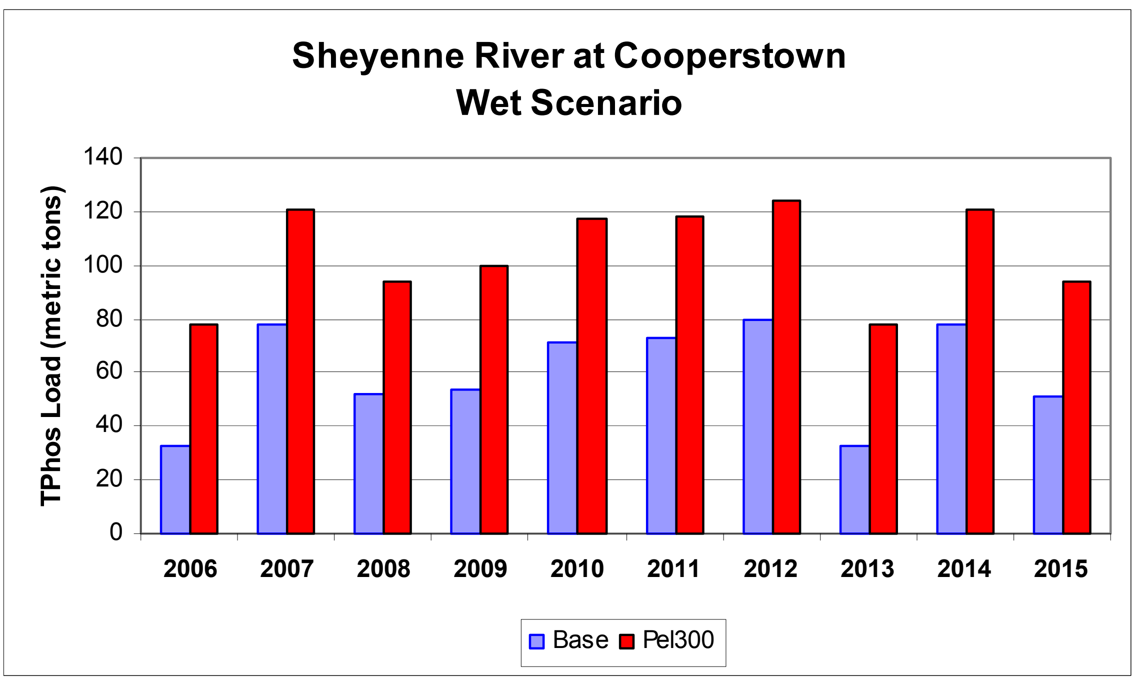

Figure 5-13: Phosphorus Loads to Lake Ashtabula

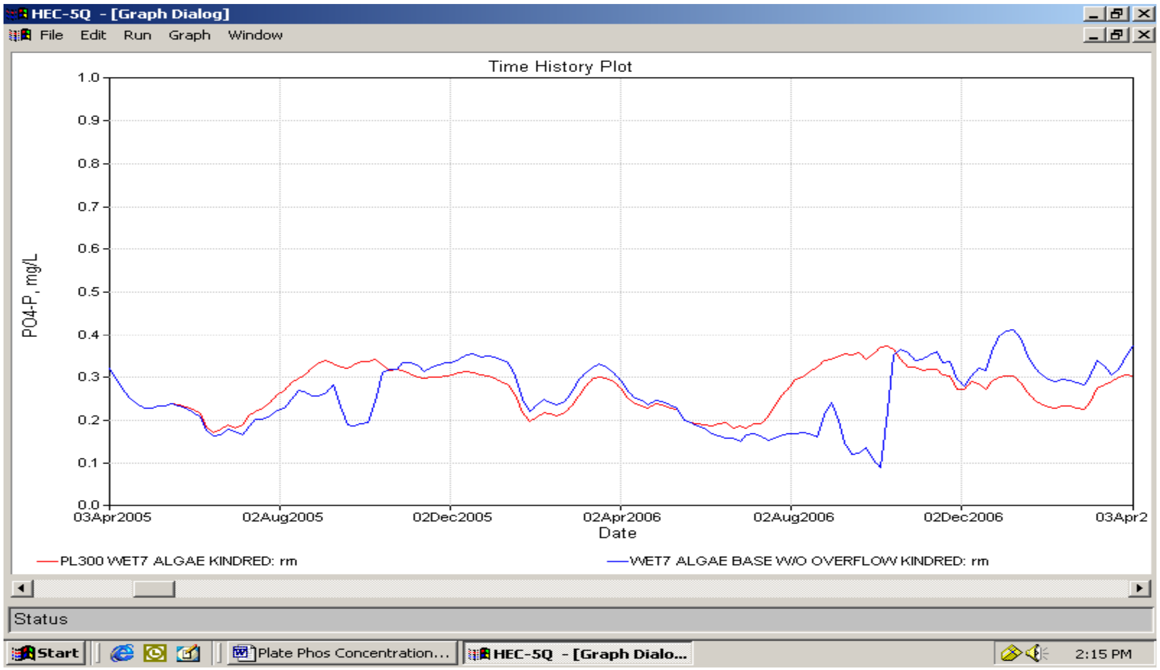

Figure 5-14: Phosphorus Concentrations below Lake Ashtabula (at Kindred) With and Without Pelican Lake 300-cfs Outlet

On the Red River of the North at Halstad, the ambient phosphorus concentration would remain at or below the baseline condition (Figure 5-15) because the increased flow of the Sheyenne River, even with its Devils Lake phosphorus load, would dilute the Red River solution. The model indicates that most of the increased load from Devils Lake shows up on the Red River at Halstad (about 40 metric tons/year) and amounts to about a 3.5-percent increase over the base condition load during the first 10 years (see Appendix A).

On the Red River of the North at Emerson, the change in concentration of phosphorus is negligible and imperceptible in the plots (See Appendix A). The model accounts for most of the 40 metric tons/year coming out of Devils Lake. At Emerson, it amounts to a 2.1-percent increase over the base condition during the first 10 years (Figure 5-16). Presently, according to a U.S. Geological Survey estimate, the U.S. portion of the Red River of the North basin contributes about 35 percent of the average annual phosphorus load to Lake Winnipeg (Stoner, J.D., Lorenz, D.L., Goldstein, R.M., Brigham, M.E., and Cowdery, T.K., 1998 Water Quality in the Red River of the North Basin, Minnesota, North Dakota, and South Dakota, 1992-95: U.S. Geological Survey Circular 1169, on line at URL:http://water.usgs.gov/pubs/circ1169, updated April 21, 1998). Many Canadians fear that the ecology of Lake Winnipeg is at risk due to various major changes in human activity over the past 30 years that have increased nutrient loading and may be changing the lake's nutrient carrying capacity and accelerating eutrophication. Those activities include different agricultural practices, expansion of livestock and food processing industries, increases in human populations, and large-scale hydroelectric development

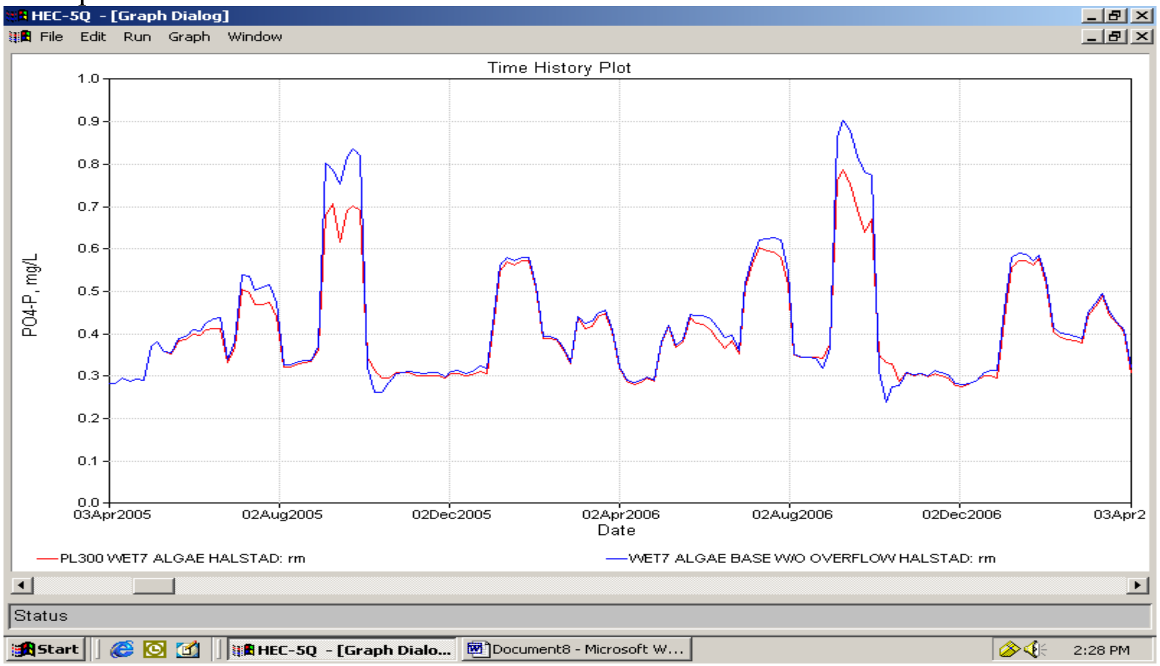

Figure 5-15: Phosphorus Concentrations on the Red River at Halstad With and Without a Pelican Lake 300-cfs Outlet

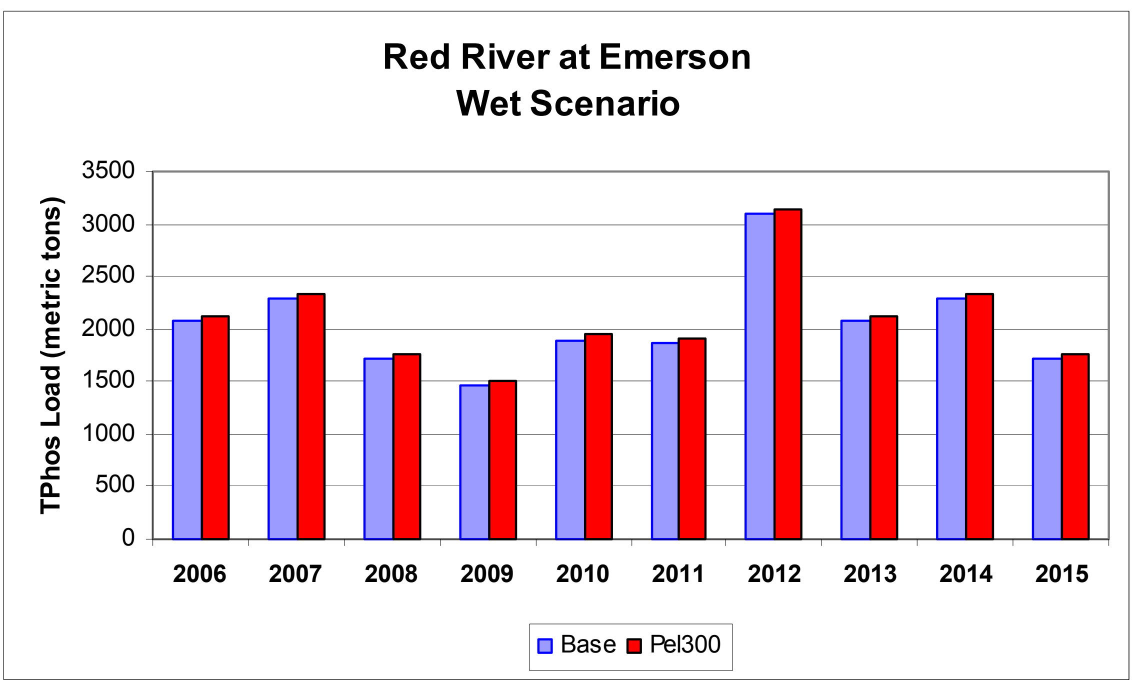

Figure 5-16: Phosphorus Loadings on the Red River at Emerson

that has disrupted normal patterns of flow and sediment transport, affecting light penetration and favoring algae and nuisance aquatic plant growth. One of the most challenging aspects of the Canadian management strategy planning is sorting out specific cause and effect terms (Manitoba Conservation, 2000, Development of a Nutrient Management Strategy for Surface Waters in Southern Manitoba, Information Bulletin 2000 – 02E, on line at <URL:http://www.gov.mb.ca/environ/prgareas/water/nutrmgt.pdf). A Devils Lake outlet could further complicate that problem.

Hardness Effects

Hardness is not a specific substance but a term commonly used in water treatment technology to express the amount and activity of polyvalent metallic ions, especially calcium and magnesium, that affect lathering charactistics of soap and rates of scale formation in water heaters and boilers. Measures of hardness, usually expressed as the equivalent concentration as calcium carbonate (CaCO3), are useful for calculating lime and soda dosages required to achieve "softening" objectives. Waters with hardness in the range of 150 to 300 mg/l as CaCO3 are generally considered to be "hard." Waters with hardness >300 are considered to be "very hard."

Predictions of total hardness, generated by the HEC-5Q model, were used in the Downstream Water Users Study (presented elsewhere in this report) to estimate increased municipal and industrial water treatment expenses and mitigation costs that might be associated with Devils Lake outlet operations.

The State of North Dakota has not established numerical standards for hardness for the Sheyenne River and the Red River of the North. The State of Minnesota's hardness standard for the Red River of the North is 250 mg/l as CaCO3. Monitoring data (USGS) during the period of record 1961-1983 at Halstad indicate that the standard was exceeded in more than 50 percent of observations. The HEC-5Q model simulations also indicate exceedance of the standard most of the time in the base condition. Devils Lake outlet operations would add to the magnitude of those exceedances except during the episodes of natural overflow in the wet scenario (Figure 5-17). Figures 5-18 through 5-20 describe the relative conditions during the first few years under the Moderate 1455 scenario. The marginal effects in the wet scenario (not shown) are less severe.

Sodium Effects

The State of North Dakota's water quality standards for sodium on the Sheyenne River and the Red River of the North are 60 percent and 50 percent (sodium as a proportion of total cations), respectively. The State of Minnesota's standard for the Red River is 60 percent. The standards for percent sodium are intended to protect agricultural beneficial uses of water where water is used for irrigation. The amount of sodium relative to other ions present can be important because a high percentage of sodium in certain types of soils can cause soil conditions adverse to plant growth. Predictions of percent sodium and sodium adsorption ratio (SAR), another parameter relevant to

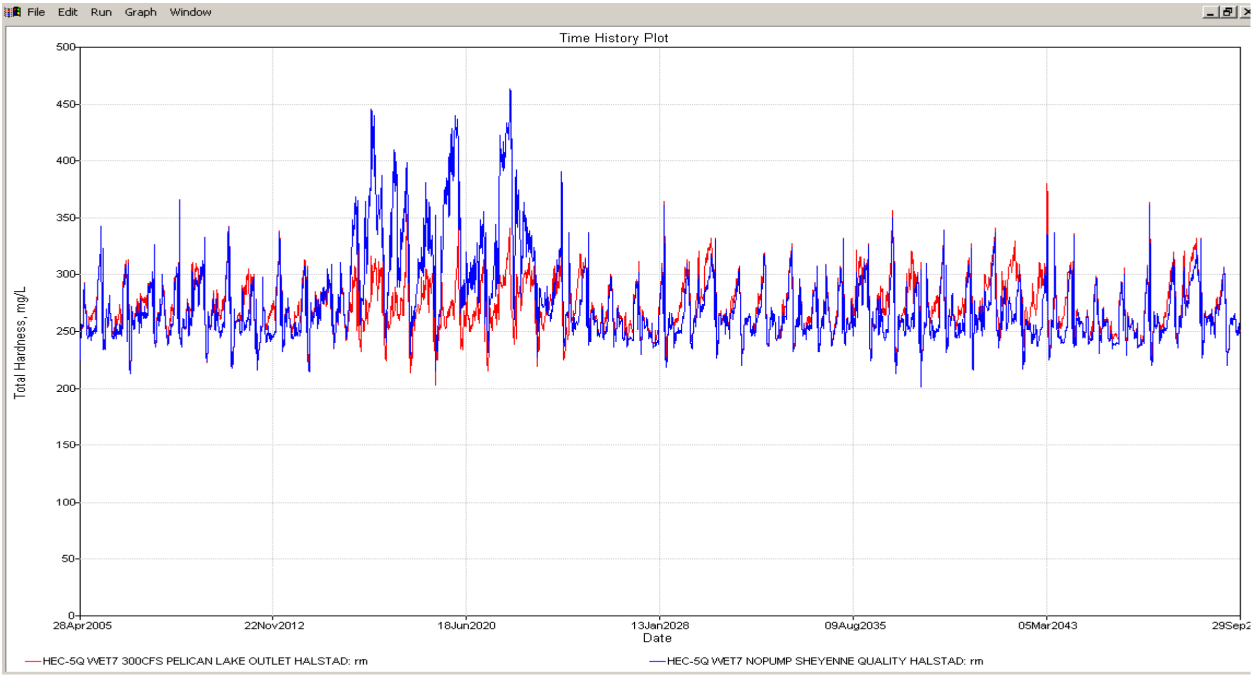

Figure 5-17: Red River at Halstad, Wet Scenario Including Devils Lake Overflow

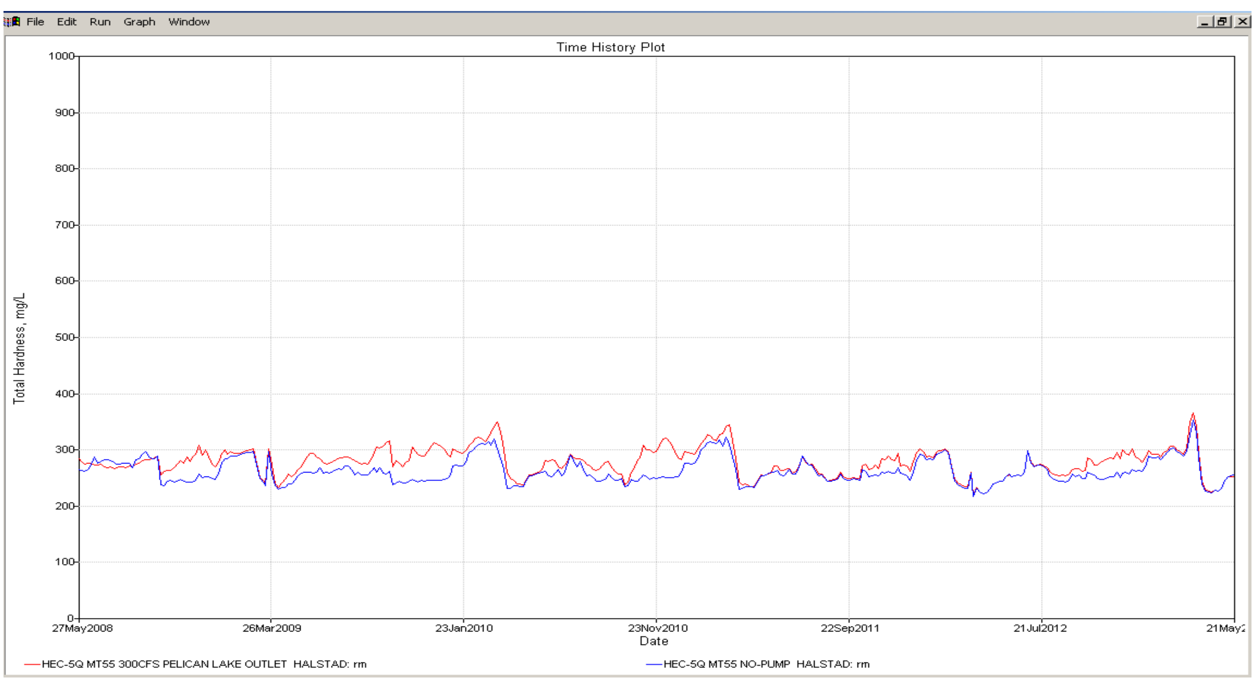

Figure 5-18: Red River at Halstad, Moderate 1455 Scenario

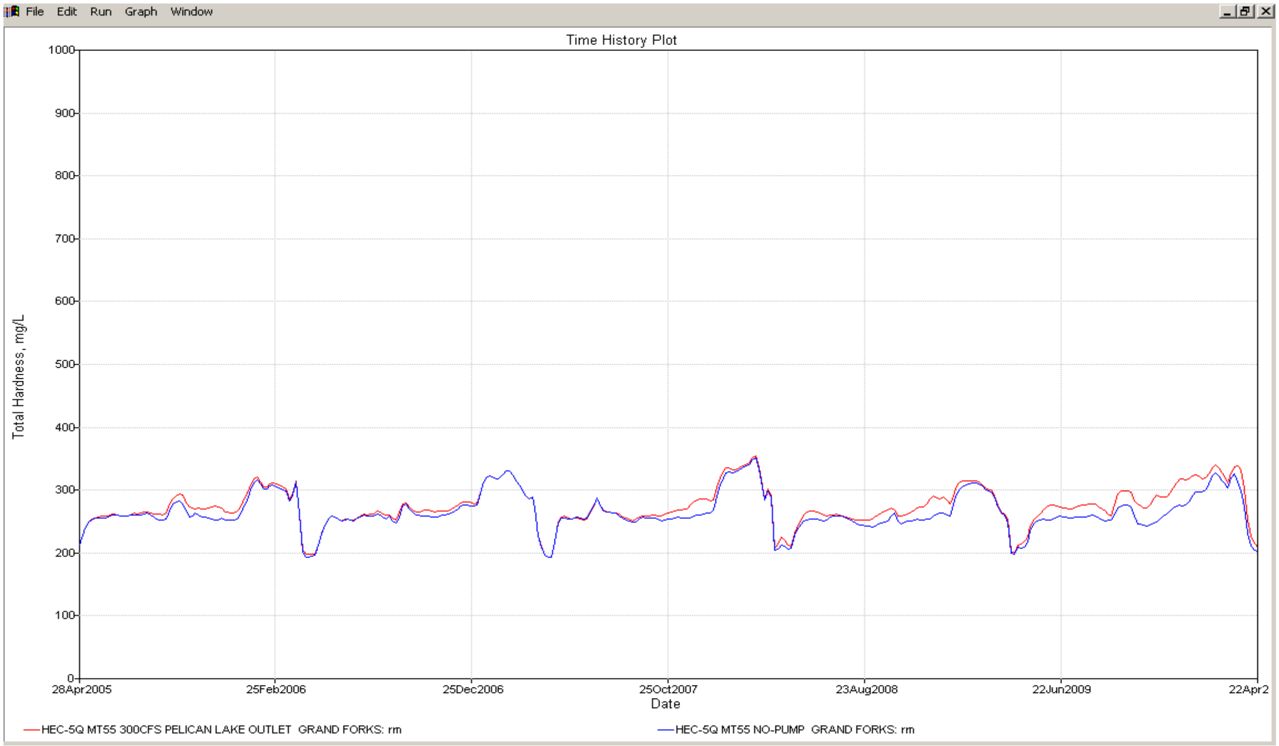

Figure 5-19: Red River at Grand Forks, Moderate 1455 Scenario

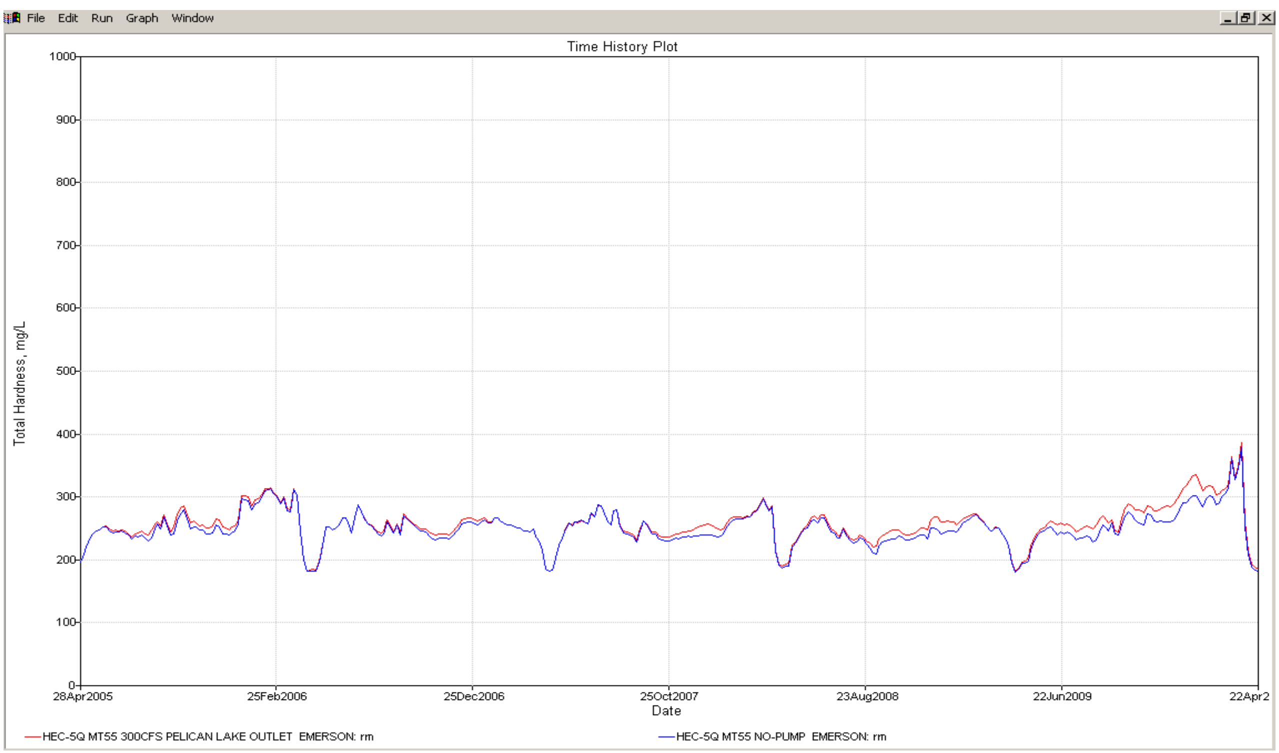

Figure 5-20: Red River at Emerson, Moderate 1455 Scenario

irrigation use, were calculated in a spreadsheet based on TDS and relative volumes (of water) predictions from the HEC-5Q model in combination with reach-specific relative proportions of major ions data from long-term historic monitoring. The predictions of percent sodium and SAR were used in the Soil Salinity Study [findings presented elsewhere in this report]. Figures 5-21 and 5-22 indicate that Pelican Lake outlet operations would cause increases in percent sodium on the Sheyenne River and Red River of the North. The magnitude of those increases would exceed the North Dakota antidegradation significance threshold (>15-percent increase), but would not exceed water quality standards.

Chloride Effects

The State of North Dakota's standard for total chloride for the Sheyenne River is 175 mg/l. Both Minnesota and North Dakota assign a standard of 100 mg/l for total chloride on the Red River of the North. HEC-5Q model simulations indicate that the concentration increases (>15 percent) would invoke North Dakota antidegradation procedures but that the standards would not be exceeded except in the case of a natural overflow (Figures 5-23 and 5-24). Modeled chloride information was used in the environmental effects analyses presented in Appendix C.

Mercury Effects

Mercury is ubiquitous in the environment and comes from natural sources as well as air and water pollution. It generally does not occur in surface waters in concentrations that are directly toxic, but under certain environmental conditions, inorganic mercury converts to an organic form, methylmercury, which is a very potent neurotoxin. Most organisms that ingest mercury do not excrete very much of it, so it becomes more concentrated at each higher trophic level. During the early 1990's, the discovery that sport fish in Devils Lake were significantly contaminated with toxic methylmercury raised not only the human health concern but also concern that the stigma of the issue might damage the local economy, (sport fishing and associated tourism are major components).

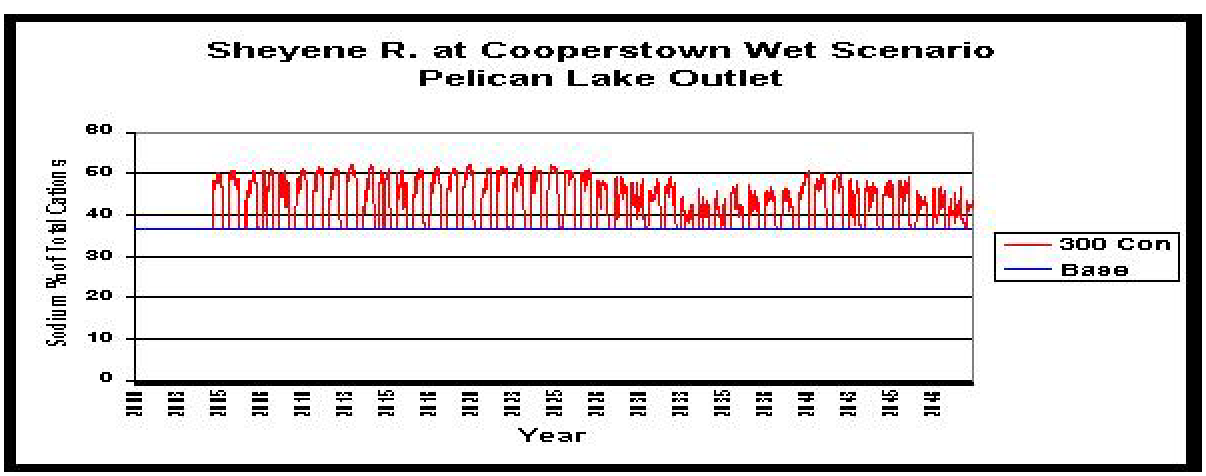

Figure 5-21: Sodium Levels for Pelican Lake Outlet Alternative, Sheyenne River

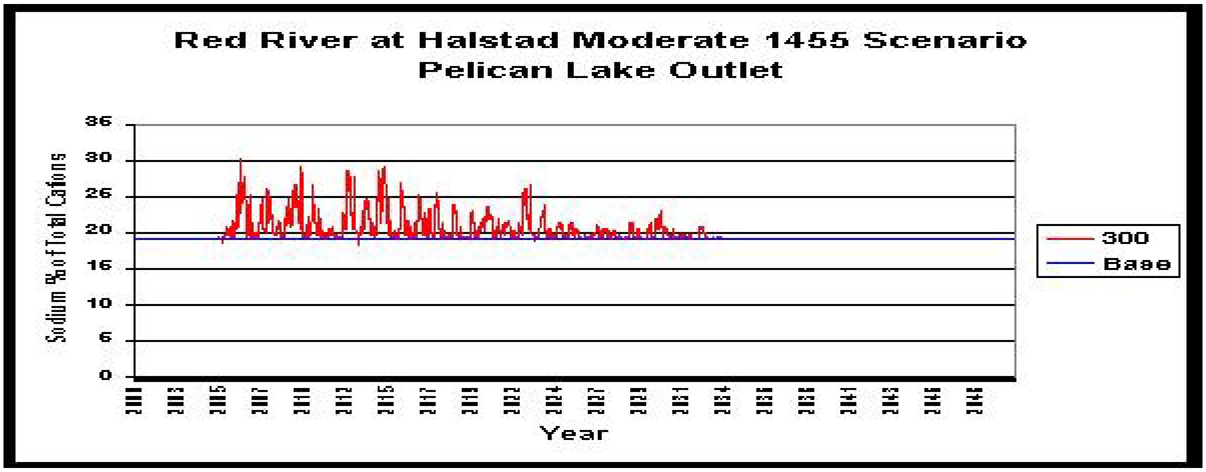

Figure 5-22: Sodium Levels for Pelican Lake Outlet Alternative, Red River at Halstad

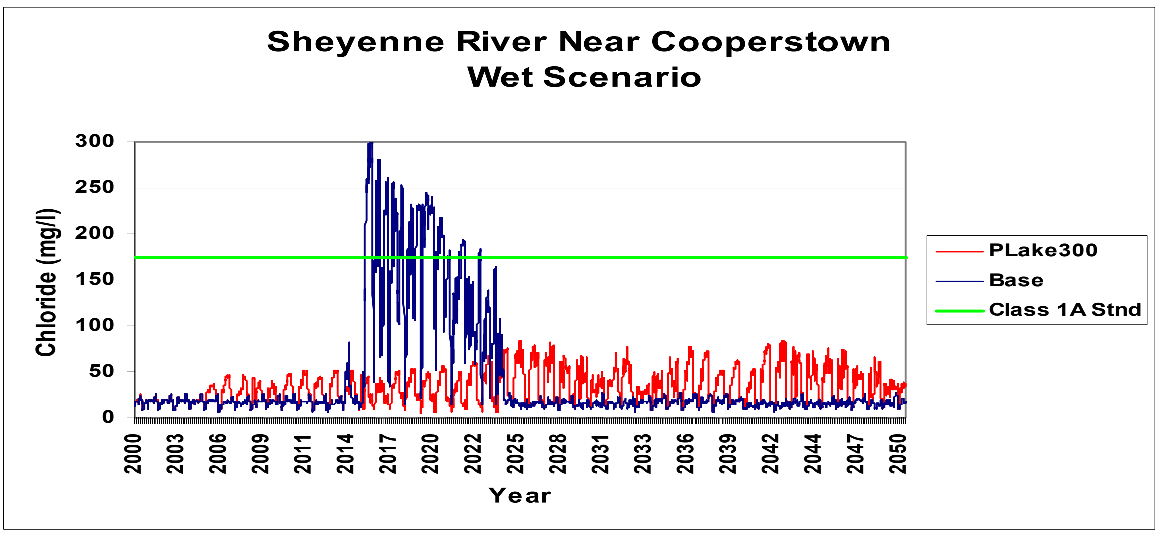

Figure 5-23: Chloride Levels for Wet Scenario, Sheyenne River near Cooperstown

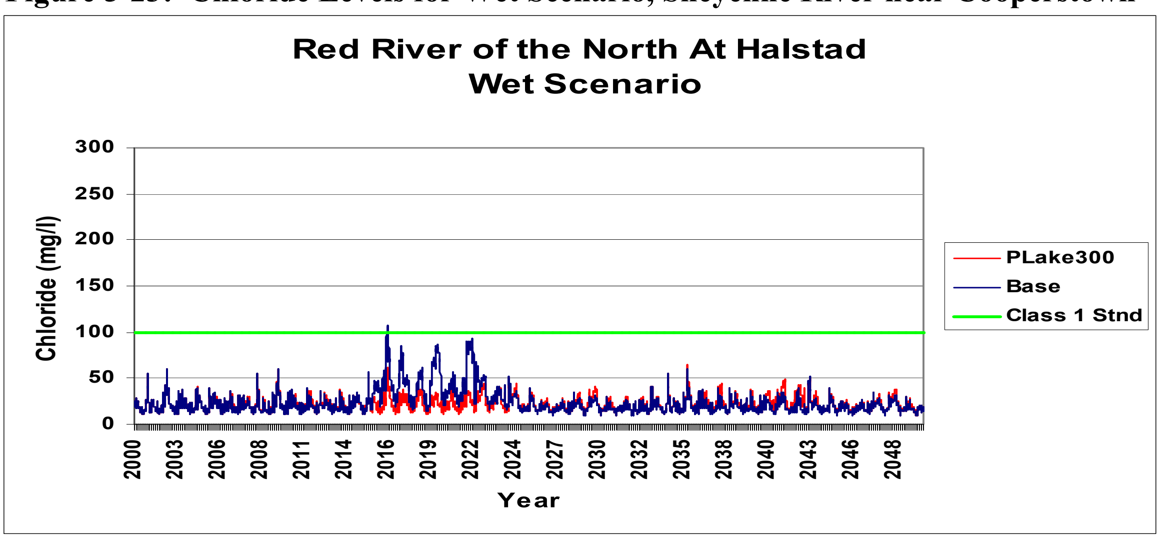

Figure 5-24: Chloride Levels for Wet Scenario, Red River of the North at Halstad

Many States, including North Dakota and Minnesota, have reacted to the potential public health risk of mercury-contaminated fish by issuing very restrictive fish consumption advisories. The need for evaluating the possible effects of increased mercury loading that would be introduced to downstream waters by a Devils Lake outlet was identified during the scoping process. Because data available in the Devils Lake and Red River basins were insufficient to describe baseline ambient conditions including variables affecting mobilization, fate, and transport of methylmercury, the Corps funded the USGS to perform a reconnaissance level investigation.

Analysis of mercury in water is very expensive because it requires application of ultra-clean sampling and laboratory protocols that call for taking extreme precautions to avoid contamination of sample water during sampling and analysis. Because of the high cost, it was practical only to perform a reconnaissance level survey of the type that would be necessary for scoping of more comprehensive systemic or site-specific analyses. The sampling design was limited to determining mercury concentrations in various forms and other ambient physical and chemical conditions at the times of the samplings. The study provided enough information to begin to describe some of the fate and transport mechanisms including some of the variables that affect transformation of inorganic mercury to methylmercury and mercury's association with suspended solids. The study did not measure or describe movement of mercury along biological pathways such that one might predict quantitative effects of outlet operations. Such a study would be extremely difficult to design on a system-wide scale considering that so many of the time-varying physical, chemical, and biological variables in their diverse and changing environments are unpredictable.

Samples were collected at 16 sites, consisting of 8 lake or wetland sites, and 8 stream sites. The lake/wetland sites included one wetland in the Devils Lake upper basin, five sites throughout the Devils Lake chain, and two sites in Lake Ashtabula. The lake and wetland sites were sampled in mid-March and in mid-summer. Stream sites were sampled during spring snowmelt runoff and in mid-summer. The stream sites included an upper basin tributary to Devils Lake (Starkweather Coulee), three sites on the upper and lower reaches of the Sheyenne River, three sites on the Red River of the North, and one site on the Red Lake River. Samples were analyzed for filtered and unfiltered total and methylmercury. The samples were also analyzed for major ions and selected trace metals, filtered and unfiltered organic carbon, and field-measured properties including specific conductance, temperature, pH, and dissolved oxygen. The data presented on Figures 5-25 and 5-26 were derived from the draft USGS report (Sando and others, 2002),[1] as was the following summary information.

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[1] *Sando, S.K., G.J. Wiche, R.F. Lundgren, B.A. Sether. 2002. "Reconnaissance Investigation of Mercury in Lakes, Wetlands, and Rivers in the Red River of the North Basin, North Dakota, February." U.S. Geological Survey. Unpublished manuscript.*

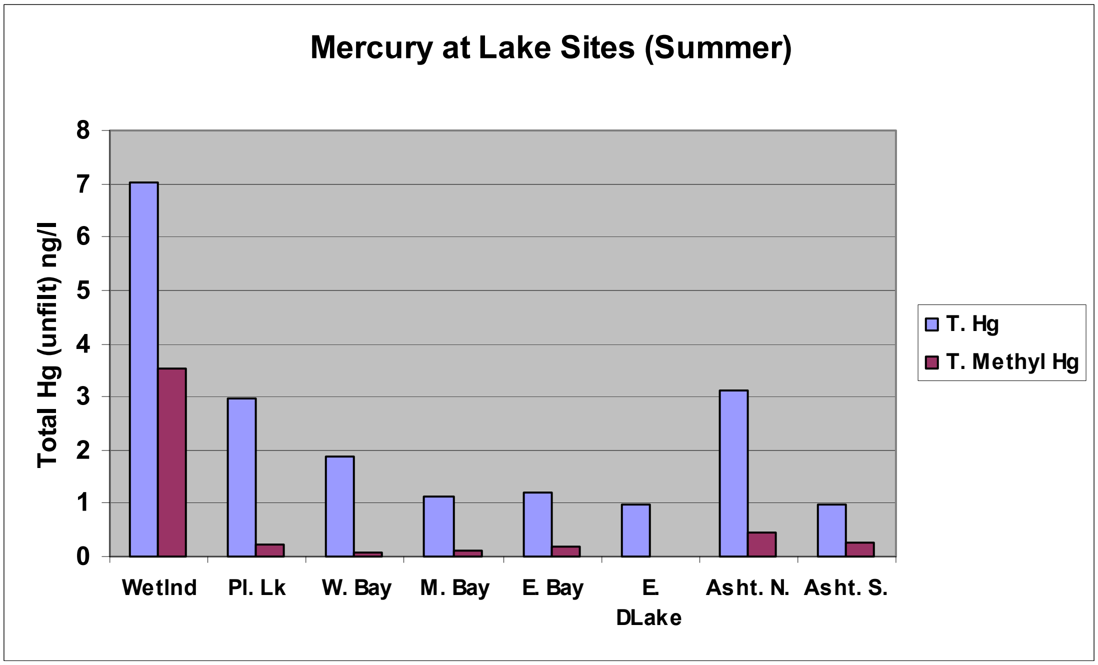


Figure 5-25: Total (unfiltered) Mercury and Methylmercury at Lake Sites

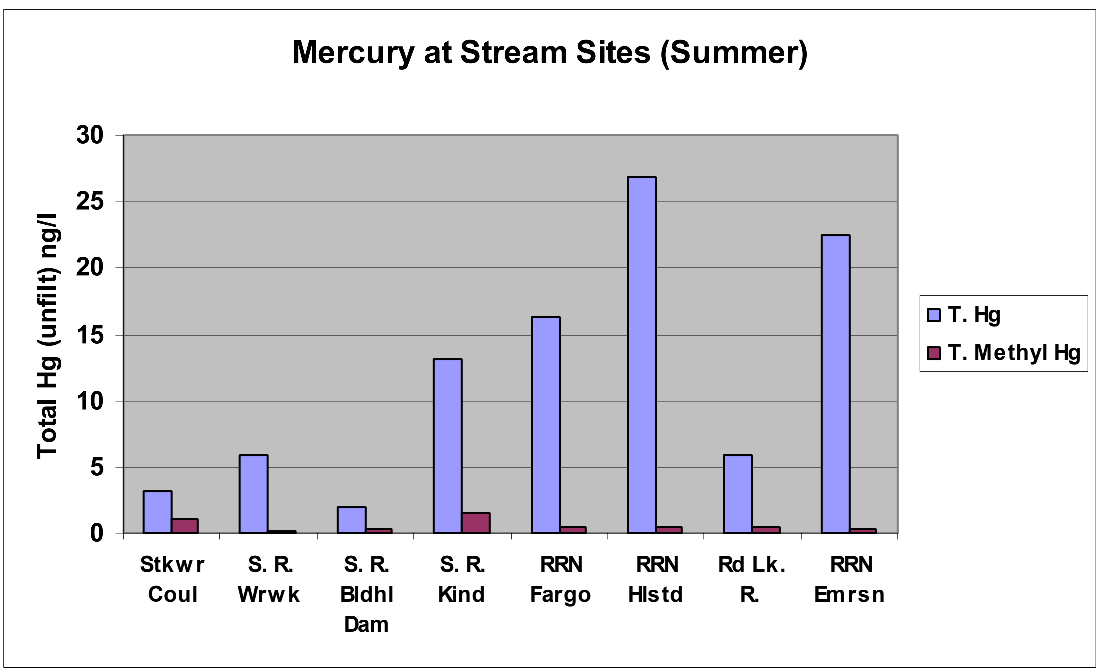


Figure 5-26: Total (unfiltered) Mercury and Methylmercury at Stream Sites

All of the lake sites in the survey and the wetland site have sulfate concentrations high enough to permit sulfate reduction, which is the process that converts inorganic mercury to methylmercury. There are also high enough sulfate concentrations (>50 mg/l) that under certain site-specific conditions, mercury methylation might be inhibited.

The wetland site in the Devils Lake upper basin has very favorable conditions for mercury methylation and exhibits a relatively high ratio of methylmercury to total mercury. Unfiltered methylmercury in the wetland site is about 10 times higher than in the Devils Lake sites.

The concentration of total mercury generally is higher in Pelican Lake than in the rest of the Devils Lake chain. Similarly, the total mercury concentration in the upper end of Lake Ashtabula is greater than at the more downstream site near the dam. The ratio of methylmercury to total mercury generally is slightly greater in Lake Ashtabula than in Devils Lake.

Total mercury concentrations generally are substantially higher in the stream sites than in the lake sites, indicating an association of mercury with suspended sediment. There is a substantial loss of mercury load between the upper Sheyenne River and Baldhill Dam, indicating that Lake Ashtabula is a sink. The loss of mercury in Lake Ashtabula may be due to processes such as sedimentation, demethylation and subsequent volatilization, and/or uptake and bioaccumulation by aquatic organisms.

Mercury load substantially increases on the Sheyenne River between Baldhill Dam and Kindred, suggesting that there is a major source of mercury from tributaries or from suspended sediment loading downstream of the dam.

On the Red River of the North, there is a large increase in mercury loads in the reach between Fargo and Halstad that is much larger than can be accounted for by inputs from the Sheyenne River. This indicates that there may be other substantial sources of mercury to this reach, including other tributaries besides the Sheyenne River, flux of mercury from stream sediments, atmospheric deposition, and various sources associated with the City of Fargo [and Moorhead].

There appears to be a loss of mercury between the Halstad and Emerson sites on the Red River of the North, which may be due to such processes as volatilization, deposition in sediments, and uptake by biota.

The USGS concluded in its draft report, presently under peer review, that a Devils Lake emergency outlet would be unlikely to cause substantial impacts in the Sheyenne River and the Red River of the North. The report stated that there could be more significant effects on Lake Ashtabula because the hypereutrophic lake provides conditions favorable for mercury methylation, as evidenced by relatively large concentrations of methylmercury and relatively large ratios of unfiltered methylmercury to unfiltered total mercury.

Other Downstream Water Quality Effects

The HEC-5Q model generates output for numerous physical and chemical parameters not discussed above because there are no indications of adverse effects. These parameters include temperature, dissolved oxygen, pH, alkalinity, ammonia, chlorophyll, benthic algae, carbon dioxide, dissolved and particulate organic material, inorganic particulate material, flow, and water level. There is also a Devils Lake tracer that serves as a virtual dye for observing the specific presence of Devils Lake water in the downstream reaches. Some of that output is presented and discussed in Appendix A; much of it is best observed by using the H5QGUI (Graphical User Interface), which facilitates user-interactive browsing of output data using various plotting and animated graphing utilities (available on request).

Effect of the Sand Filter on Downstream Water Quality

Some of the water quality effects described in the preceding paragraphs would be moderated by the proposed sand filter by intercepting nutrients and contaminants such as mercury associated with biota and suspended sediment. Monitoring data from Devils Lake indicate that about 96 percent of the nitrogen and approximately 19 percent of the phosphorus is associated with particulate substances during the open water season and so would be retained by the sand filter. The previous discussion of downstream nutrient effects states that about 40 tons of phosphorus per year would be introduced into the Sheyenne River. Action of the sand filter could reduce the phosphorus load to about 32 tons per year and would likely cause reduced nitrogen concentrations in the upper Sheyenne River and Lake Ashtabula. The filter would also intercept a significant portion of the mercury load because most of it is associated with suspended sediment and plankton. The filter would not likely detain dissolved substances such as sulfate and TDS.

Effects of Uncontrolled Overflow from Stump Lake

Figures 5-27 through 5-29 compare the downstream concentration effects of West Bay 480-cfs unconstrained outlet operations and Pelican Lake 300-cfs constrained operations with the effects of the uncontrolled overflow condition during the first 20 years of operation. At Valley City on the Sheyenne River with outlet operations, the sulfate concentration would remain at or above 400 mg/l for much of the entire 20-year period compared with the base condition where it would rarely exceed 180 mg/l. In the overflow scenario, the effects would begin to appear in the year 2014 with much higher concentration peaks and sustained higher levels. Pelican Lake outlet operations would produce sulfate concentrations between 200 and 300 mg/l much of the time. From the perspective of water users at Valley City, both the 480-cfs outlet operations and the natural overflow scenarios would necessitate obtaining an alternative water supply source or extended source water treatment and acceptance of other environmental changes. Pelican Lake outlet operations would also significantly degrade the water supply source, likely necessitating extended or additional treatment. An important consideration from the

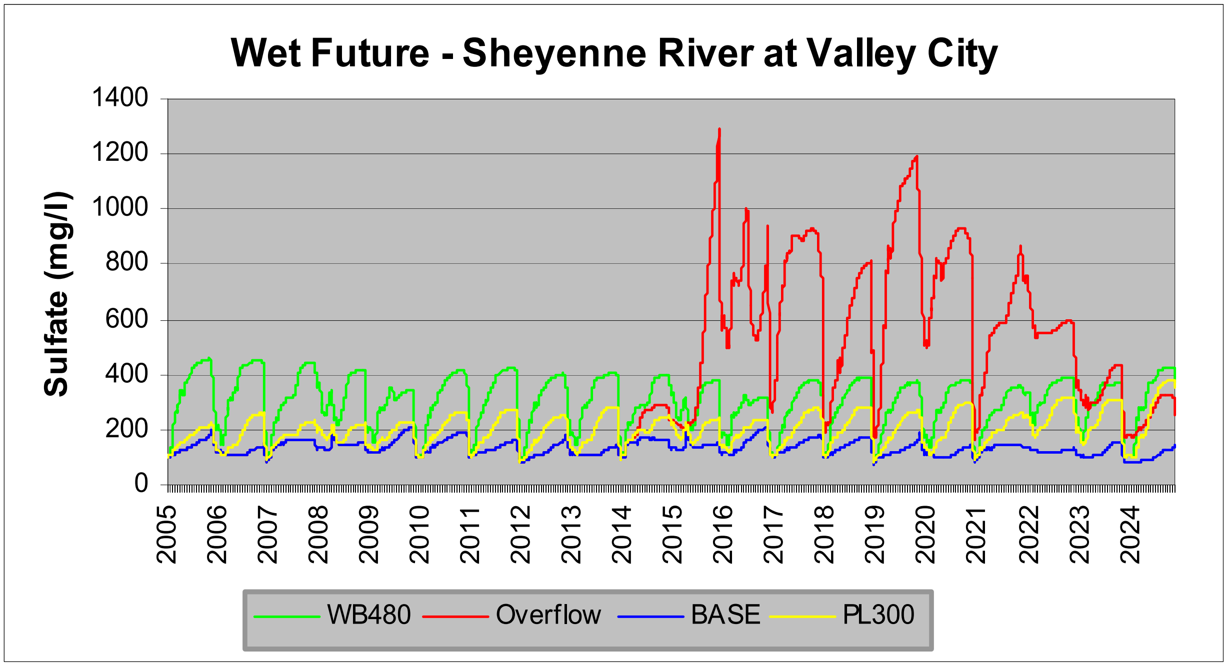


Figure 5-27: Sulfate Concentrations, Sheyenne River at Valley City

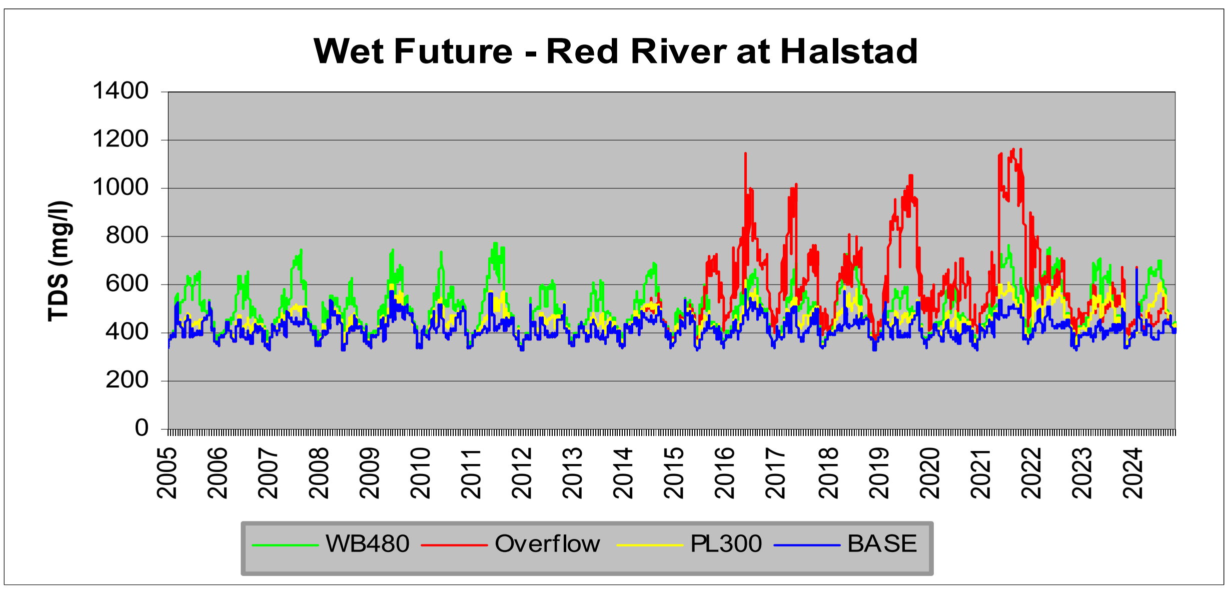


Figure 5-28: TDS Levels, Red River at Halstad

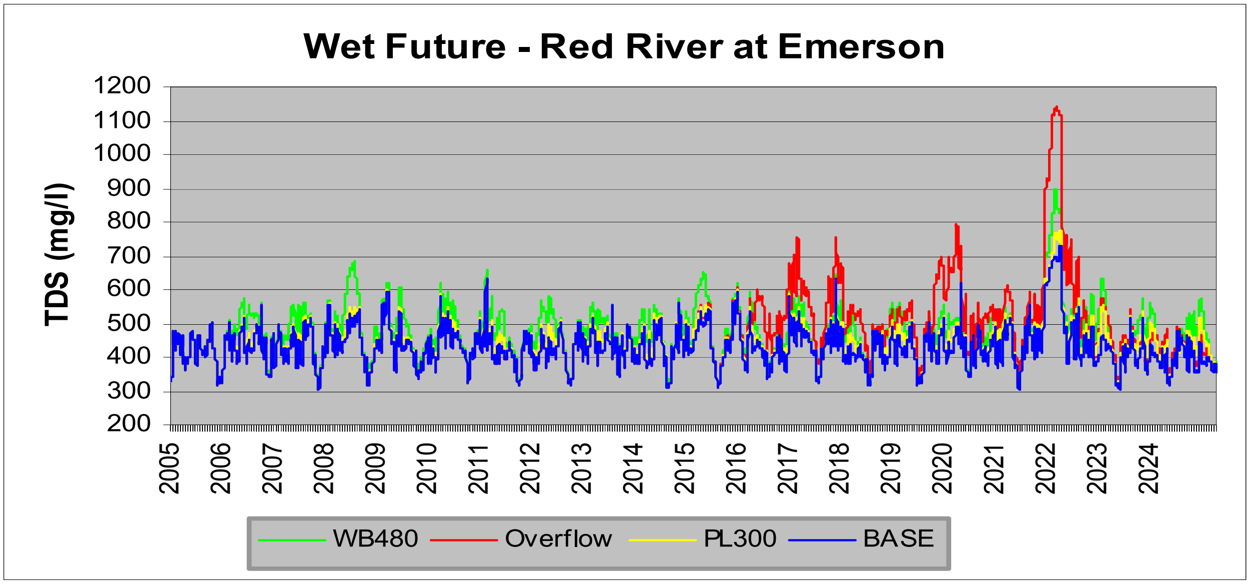


Figure 5-29: TDS Levels, Red River at Emerson

perspective of the Sheyenne River water users is that, with an outlet in place and operating, the effects of operations would be certain while the prospects for future uncontrolled spill effects would be speculative.

Figure 5-13 described phosphorus concentrations that would occur in Lake Ashtabula. With outlet operations, the TDS and sulfate concentrations would also increase during the summer to nearly match the quality of the outlet water, whether from Pelican Lake or West Bay. The overflow scenario assumes the quality of the Stump Lake water. The elevated TDS and sulfate condition would be sustained throughout the winter until the spring snowmelt water displaces it and the cycle would repeat.

On the Red River near Halstad with 480-cfs unconstrained outlet operations, the TDS concentration would remain at or above 500 mg/l (the regulatory limit) for much of the entire 20-year period, compared with the base condition in which the TDS standard would rarely be exceeded. In the overflow scenario, the effects would begin to appear in the year 2014, with higher concentration peaks and sustained high levels.

Pelican Lake outlet operations would cause some increase in the frequency and magnitude of concentrations in excess of 500 mg/l. From the perspective of people who use the Red River, and the State of Minnesota, which has the right to object if its water quality standards are exceeded, both the 480-cfs unconstrained outlet operation and the overflow scenarios would likely necessitate expensive alternative water supply sources or treatment technology and acceptance of other environmental changes. Pelican Lake 300-cfs outlet operations would slightly degrade the quality of the water supply source but probably would not necessitate extraordinary treatment expense. An important consideration from the Minnesota perspective is that, with an outlet in place and operating, the effects of operations would be certain while the prospects for future uncontrolled spill effects would be speculative.

On the Red River near Emerson, Manitoba, with 480-cfs unconstrained outlet operations, the TDS concentration would remain at or above 500 mg/l (objective defined pursuant to the Boundary Waters Treaty) for more of the time of the 20-year period, compared with the base condition in which the TDS objective would only sometimes be exceeded. In the overflow scenario, the effects would begin to appear in the year 2014, with higher concentration peaks and sustained levels. Pelican Lake 300-cfs outlet operations would cause some increase in the frequency and magnitude of concentrations exceeding 500 mg/l. From the perspective of Canadians who use the Red River, the Province of Manitoba, and the Government of Canada, both the 480-cfs unconstrained outlet operations and the overflow scenarios would result in measurable environmental changes that could be costly. The legislation for construction authorization states that "the plans for the emergency outlet shall be reviewed, and to be effective, shall contain assurances provided by the Secretary of State, after consultation with the International Joint Commission, that the project will not violate the requirements or intent of the Treaty between the United States and Great Britain…." Pelican Lake 300-cfs outlet operations would slightly degrade the quality of the water supply source but probably would not necessitate extraordinary treatment expense. An important consideration from the Canadian perspective is that, with an outlet in place and operating, the effects of outlet operations would be certain while the prospects for future uncontrolled spill effects would be speculative.

SENSITIVITY ANALYSIS

Moderate Future Scenarios

To better understand the sensitivity of assumptions used for future lake conditions, both with and without a project, the alternatives were compared to other possible future conditions as part of the sensitivity analysis. More moderate futures (with a maximum lake elevation of 1455 and 1450) were evaluated as an alternate base condition. The traces used for the various scenarios in terms of lake stages are shown on Figure 5-30. The alternatives were not evaluated against the dry future noted on that figure.

1455 Peak Lake Level

This moderate future trace is one of the 10,000 stochastic traces, and serves as a representative of approximately 25 percent of those traces. It rises to a peak level of 1455 at about year 2014 and then recedes for the remaining 50 years. Table 5-14 displays information on cost-effectiveness, highest lake level, and water quality impacts (as measured in terms of percent of time exceeding water quality parameters at three downstream locations). The stage effectiveness for outlet alternatives, as measured against this moderate future scenario, is shown on Figure 5-31.

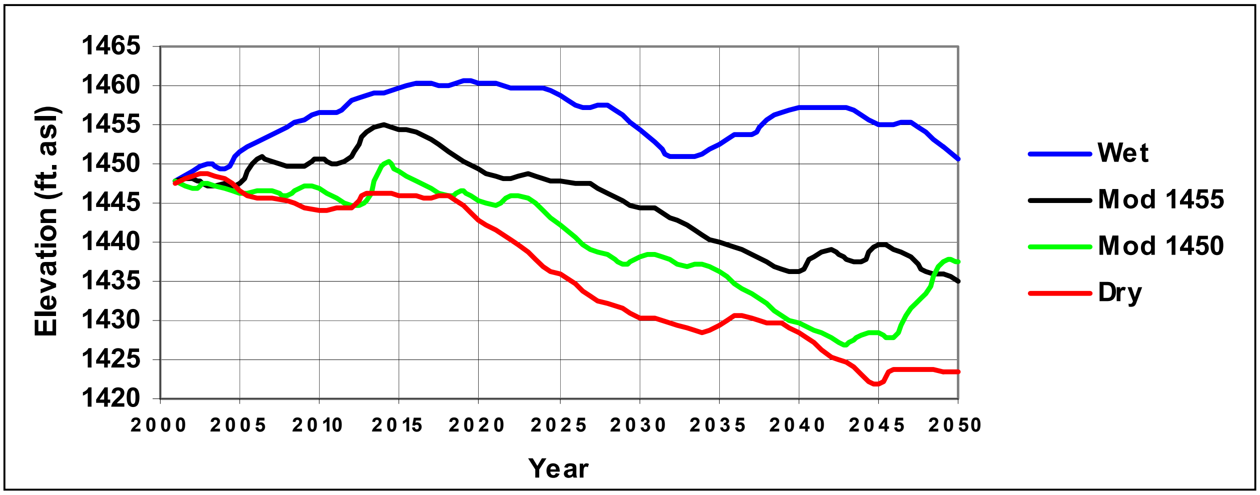


Figure 5-30: Devils Lake Elevation Scenarios

The moderate future results show net benefits that are slightly higher than those computed using the stochastic analysis. This could be anticipated, because the average peak lake level for the stochastic analysis was 1451.7 and the median was 1450.1. Because this trace has a higher peak lake level than the average stochastic trace, it results in larger net benefits because there are more damages to reduce. However, only one of the six alternatives had positive net benefits and a benefit-cost ratio greater than 1 – the Pelican Lake 300-cfs constrained outlet. Note that only some of the alternatives were analyzed for the 1455 moderate future.

<u>1450 Peak Lake Level</u>

This moderate future trace is one of the 10,000 stochastic traces, and serves as a representative of approximately 30 percent of those traces. Table 5-15 displays information on cost-effectiveness, highest lake levels, and water quality impacts. Figure 5-32 shows the stage effectiveness of various alternatives, as compared to a moderate future scenario of the lake's peak level at 1450 without an outlet. It rises to a peak level of 1450 at about year 2014 and then recedes for the remaining 50 years. It also has a second peak near the end of the 50-year period, but the maximum lake level during the second peak is much lower than the first peak.

The moderate future results show net benefits are generally slightly lower than those computed using the stochastic analysis. As mentioned earlier, the average and median peak lake levels for the stochastic analysis were 1451.7 and 1450.1, respectively. Again, the Pelican Lake 300-cfs outlet results in the highest benefit-cost ratio for the outlet alternatives, although using the most likely future, the benefit-cost ratio is only 0.38, as compared to 1.08 assuming a "No Action" base condition.

Table 5-14: Matrix of Alternatives Considering Cost-Effectiveness, Lake Stage Effectiveness, and Water Quality, Moderate Future Scenario (1455)

	Total Costs [1]	Likely Future		No Action	Highest	WQ [2]	WQ [3]	WQ [4]
	($million)	"Net Benefits"	"BCR"	"BCR"	Lake Level			
Alternatives within the Basin		($000's)						
Upper Basin Stor.-50% (UBS)					1455	0	4	11
Expand.Infrastr.Prot. (EIP)					1455	0	4	11
Raise Natural Outlet					1455	0	4	11
Outlet Alternatives								
West Bay Outlet (300 cfs)	$89	-$447	0.92	1.42	1453	0	14	14
(Peterson Coulee)								
West Bay Outlet (480 cfs)	$175	-$2,810	0.76	1.78	1452	44	63	40
(Peterson Coulee)								
Pelican Lake Outlet (300 cfs)	$120	$3,076	1.38	1.76	1450	0	23	16
Pelican Lake Outlet (480 cfs)	$215	-$3846	0.73	1.54	1448	22	48	28
Pelican Lake Bypass (480 cfs) - PL2	$232	-$5092	0.67	0.84	1450	0	7	12
Pelican Lake Bypass (480 cfs) - PL3	$328	-$8640	0.61	1.09	1449	0	7	12
East End Outlet								
Combination Alternatives								
Combination 1 (UBS, EIP)								
Combin. 2 (UBS, EIP, West Bay/300)	$153	-$202	0.98	0.95	1452		14	14
Continued Infrastr. Protection								
(this is the "likely future" base								
condition, as measured against								
no action)								

Notes:

[1] - Total costs are present worth of all costs, including annual Operation and Maintenance

[2] - Downstream water quality, as represented by percentage of time Sulfate standard of 450 mg/L is exceeded at Valley City, ND (years 2005-2014, assuming wet future scenario)

[3] - Downstream water quality, as represented by percentage of time TDS standard of 500 mg/L is exceeded at Halstad, MN (years 2005-2014, assuming wet future scenario)

[4] - Downstream water quality, as represented by percentage of time TDS objective of 500 mg/L is exceeded at Emerson, MB (years 2005-2014, assuming wet future scenario)

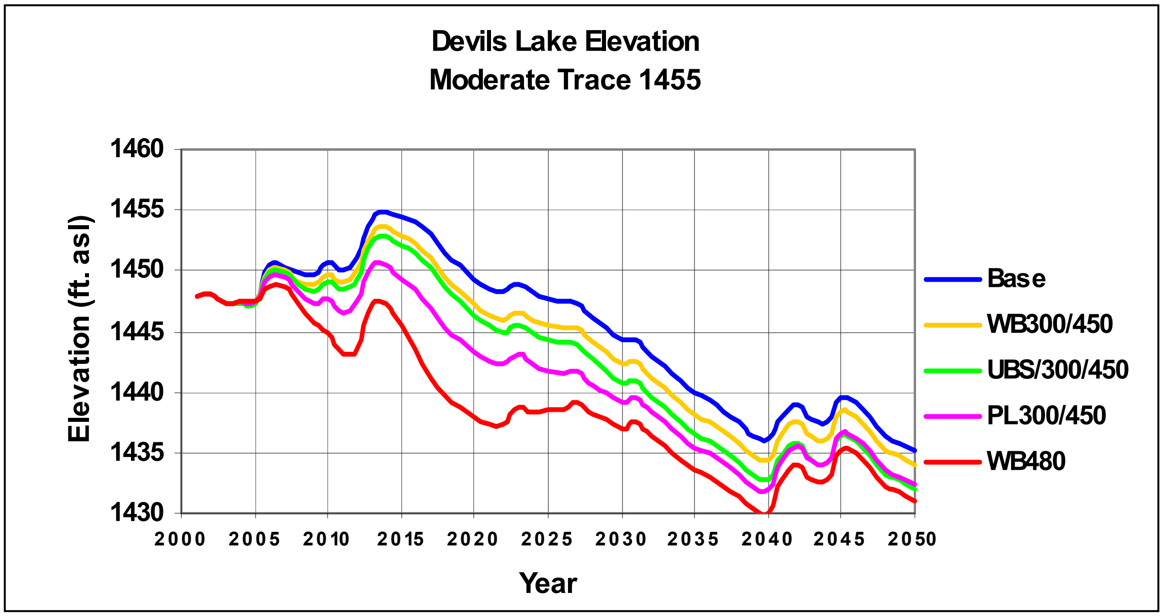


Figure 5-31: Stage Effectiveness for Outlet Alternatives Measured Against Moderate Future Scenario

(Note: The following sensitivity studies were performed using the more detailed cost estimate of the selected outlet alternative, as summarized in Table 5-22)

Erosion of the Natural Outlet

One of the assumptions for the base condition upon which alternatives were compared was that measures would be taken at the location of a natural overflow to minimize erosion. Although no design or cost estimate was developed for such measures, the features of the natural outlet raise alternative can put this assumption into perspective. The structure envisioned with that alternative included a 380-foot-wide concrete drop structure, with a cost for the structural portion of $1.1 million. This sensitivity analysis was done to evaluate the effect of the assumption of minimal erosion at the natural outlet.

Erosion of the natural outlet was evaluated as a sensitivity analysis for the wet future scenario with and without a Pelican Lake 300-cfs outlet. The analysis indicated that the outlet control point would slowly be eroded, with the maximum potential erosion occurring down to elevation 1450.8 and a peak discharge of 6,000 cfs expected to occur during year 17 of the wet future scenario. (This compares to a peak discharge of only 550 cfs when no erosion of the Tolna Coulee is assumed.) With erosion at the natural outlet, the peak lake level is reduced by 0.30 foot, and the duration of high lake levels is much smaller. As shown on Figure 5-33, peak lake levels are similar when comparing a wet future scenario, with and without erosion. However, long-term lake levels are lower if significant erosion occurs.

Table 5-15: Matrix of Alternatives Considering Cost-Effectiveness, Lake Stage Effectiveness, and Water Quality, Moderate Future Scenario (1450)

	Total Costs [1]	Likely Future		No Action	Highest	WQ [2]	WQ [3]	WQ [4]
	($million)	"Net Benefits"	"BCR"	"BCR"	Lake Level			
Alternatives within the Basin		($000's)						
Upper Basin Stor.-50% (UBS)					1450	0	2	9
Expand.Infrastr.Prot. (EIP)					1450	0	2	9
Raise Natural Outlet					1450	0	2	9
Outlet Alternatives								
West Bay Outlet (300 cfs)	$87	-$5,271	0.10	0.16	1450	0	9	13
(Peterson Coulee)								
West Bay Outlet (480 cfs)	$170	-$12085	-0.06	0.77	1447	21	35	34
(Peterson Coulee)								
Pelican Lake Outlet (300 cfs)	$117	-$4,841	0.38	1.08	1447	0	18	16
Pelican Lake Outlet (480 cfs)	$206	-$13,970	-0.01	0.68	1447	27	26	28
Pelican Lake Bypass (480 cfs) - PL2	$227	-$13,576	0.11	0.41	1449	0	3	14
Pelican Lake Bypass (480 cfs) - PL3	$324	-$18,460	0.15	0.41	1448	0	3	14
East End Outlet								
Combination Alternatives								
Combination 1 (UBS, EIP)								
Combin. 2 (UBS, EIP, West Bay/300)	$127	-$4,994	0.41	0.82	1448	0	9	13
Continued Infrastr. Protection								
(this is the "likely future" base								
condition, as measured against								
no action)								

Notes:

[1] - Total costs are present worth of all costs, including annual Operation and Maintenance

[2] - Downstream water quality, as represented by percentage of time Sulfate standard of 450 mg/L is exceeded at Valley City, ND (years 2005-2014, assuming wet future scenario)

[3] - Downstream water quality, as represented by percentage of time TDS standard of 500 mg/L is exceeded at Halstad, MN (years 2005-2014, assuming wet future scenario)

[4] - Downstream water quality, as represented by percentage of time TDS objective of 500 mg/L is exceeded at Emerson, MB (years 2005-2014, assuming wet future scenario)

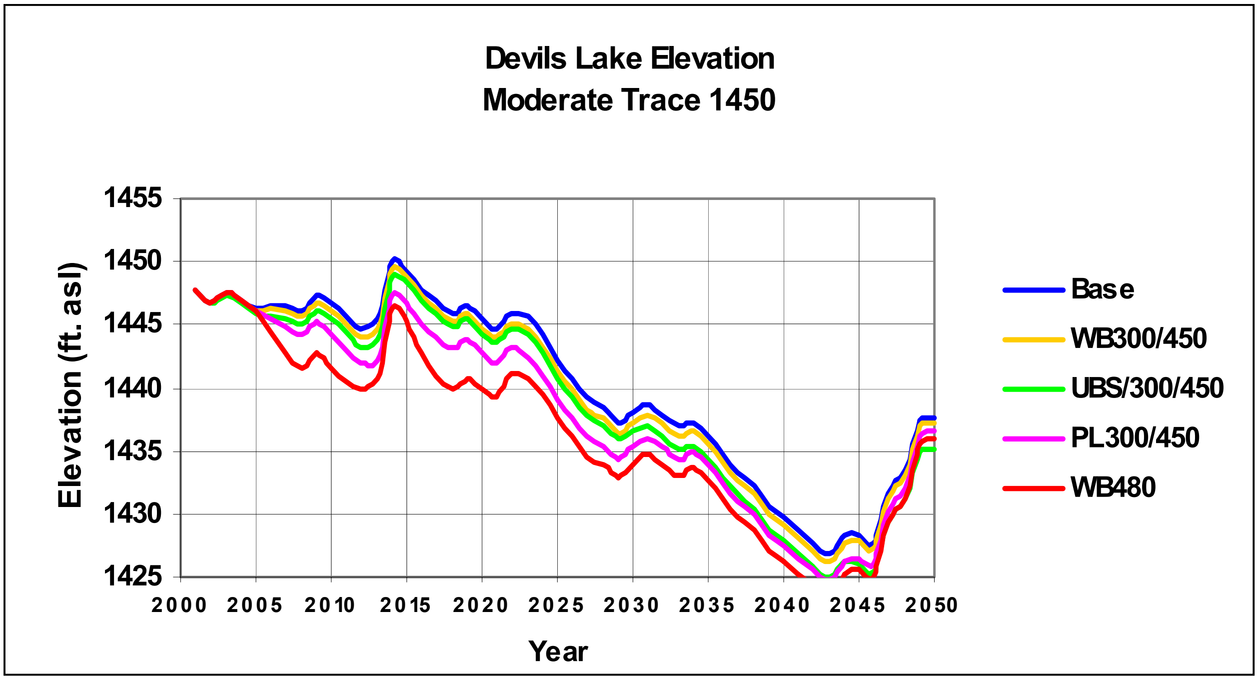


Figure 5-32: Stage Effectiveness of Various Alternatives Compared to a Moderate Future Scenario of the Lakes Peak Level Without an Outlet

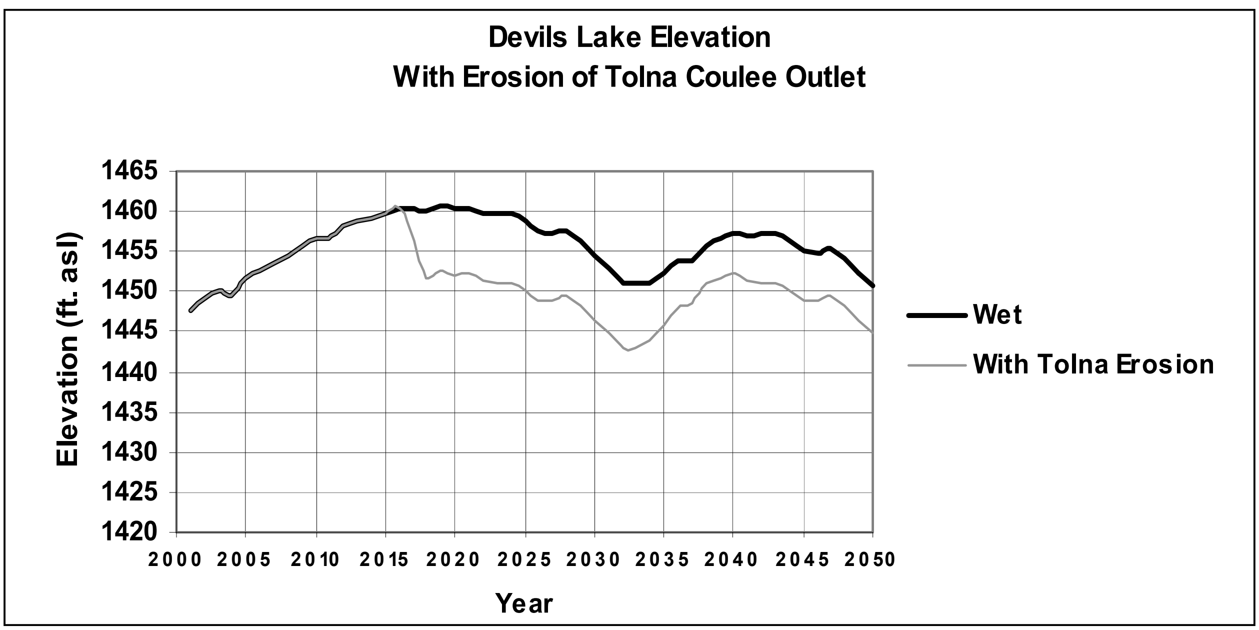


Figure 5-33: Devils Lake Elevation with Erosion of Tolna Coulee Outlet

The erosion sensitivity analysis evaluated the impacts of erosion of the overflow point and adjacent upper reaches of Tolna Coulee. The coulee upper channel profile consists of two relatively steep sections located on both sides of a broad, flat marshy area that initially controls the outflow from Stump Lake. The upstream end of this marshy area is slightly higher than the initial Stump Lake overflow point. Initially, erosion was assumed to start at the downstream end of this broad marshy area and proceed upstream to the overflow point. It was assumed that erosion would continue until the upper coulee becomes stable. Soil information at the natural outlet is limited, but suggests the soils are moderate to highly erodible.

Based on the most recent surveys, overflow from Stump Lake occurs when the lake level reaches an elevation of 1459.1 feet. The analysis indicates that the outlet control point would slowly be eroded, with the maximum potential erosion occurring down to 1450.8.

Using sediment transport rates and the volume of overflow, the time for this erosion to occur was estimated to be approximately 9 months. The sediment transport rates and associated discharge rating curves were used in the U.S. Geological Survey model to evaluate the impacts on the lake level and downstream channel characteristics.

Because of increased damages that would occur with erosion of the natural outlet, net benefits increase for all of the outlet alternatives analyzed for the wet future scenario when erosion is assumed. For the selected Pelican Lake 300-cfs outlet, the benefit-cost ratio for the wet future scenario increases from 1.54 to 1.86 when the base condition assumes erosion at the natural outlet. For the stochastic scenario, an increase in net benefits for outlet alternatives would also be expected, but not by the same degree. This is because less than 10 percent of the stochastic traces overflow over the outlet and most of those traces result in less overflow, and therefore less erosion, than is produced by the wet future scenario.

While the assumption that erosion would be allowed to occur, and that it would occur at the rate computed, increases the benefits for an outlet alternative, these benefits would be realized by any alternative that prevented erosion, such as a concrete weir that held the outlet at its overflow elevation of 1459 feet msl.

In the lake, the lands would be exposed more quickly and recovery would be more rapid. There are approximately 114,685 acres between elevations 1450 and 1459 around Stump Lake and Devils Lake.

Downstream effects resulting from the erosion of the natural outlet would be significant. There would be increased sedimentation in the Sheyenne River and Lake Ashtabula. Erosion would also increase in the Sheyenne River. There would be substantial effects to the downstream aquatic resource on the Sheyenne and Red Rivers. Higher flows, changed water quality, sedimentation, erosion, increased groundwater levels, and overbank flooding would result in the loss of aquatic and riparian habitats.

Proposed Temporary Outlet as Part of Future Conditions

The State's proposed temporary outlet was not included in the modeling and evaluation of alternatives since the certainty of implementation and actual design parameters of the plan were not determined at the time this report's analyses were being accomplished. Although the proposed plan is controversial and still has a high level of uncertainty, the state is proceeding with plans to initiate operation. The plans call for pumping 100 cfs through an outlet, which is to be primarily an open channel, from the West Bay to the Sheyenne River. There would be provisions for adding additional pumping capacity, up to 300 cfs, in the future. The operating plan would be constrained so as not to exceed sulfate concentrations of 300 mg/l or exceed 600 cfs flow in the Sheyenne River at the insertion point. The State's proposed temporary outlet is designed with a minimum pumping level of 1445. The sensitivity analysis defines the economic feasibility of the Pelican Lake 300-cfs outlet plan, assuming the State's proposed temporary outlet under the without-project conditions. In other words, the intent was to evaluate the incremental cost-effectiveness of the Pelican Lake 300-cfs outlet, assuming the temporary outlet was able to function indefinitely in the absence of the permanent outlet.

For this analysis, the without-project condition assumes construction of the State's proposed temporary outlet together with the other assumed base condition measures, such as continuation of emergency infrastructure measures. The with-project condition assumes construction of the Pelican Lake outlet and not the temporary outlet. It was assumed that construction of the Pelican Lake outlet would begin immediately and that the outlet would be operational in 2005. The temporary outlet was assumed to be in place and operational until the lake level drops to elevation 1443. The outlet would draw water from West Bay and would begin operation at a capacity of 100 cfs by May 2004 and 300 cfs by May 2006. It would be constrained to not exceed 300 mg/l sulfate concentration or 600 cfs flow at the insertion point.

Since the temporary outlet would not be constructed under the with-project conditions, the benefits of not constructing the temporary outlet were included as project benefits (similar to other features that would not have to be protected under with-project conditions).

As shown in Table 5-16, the analysis indicates that including the State's proposed temporary outlet in the most likely future without project would alter the benefit-cost ratio, but does not change the conclusions of the alternative formulation analysis. The wet future analysis shows the greatest change in the BCR, being reduced from 1.54 to 1.17.

Table 5-16: State's Proposed Temporary Outlet Operated Indefinitely

Incremental Cost Effectiveness for Pelican Lake 300 cfs Outlet (Effect on Cost Effectiveness if Temporary Outlet is included with Most Likely Future without Project)						
	Without Temporary Outlet			With Temporary Outlet		
	Annual Benefits	Net Benefits	BCR	Annual Benefits	Net Benefits	BCR
Stochastic Analysis	$2,595	($11,325)	0.19	$1,759	($12,161)	0.13
Wet Future Scenario	$22,554	$7,942	1.54	$17,072	$2,460	1.17
1455 Moderate Future	$7,818	($6,328)	0.55	$7,555	($6,590)	0.53
1450 Moderate Future	$1,847	($12,135)	0.13	$1,396	($12,585)	0.10

The flow effects on natural resources resulting from the state outlet are expected to be less than those described for the Pelican Lake outlet because less water would be pumped overall and at any particular time. This is due to the water quality constraint and conditions in West Bay. The lower outlet flow would result in smaller changes in river stage, less groundwater effects, and less flow in the river than would result from the Pelican Lake outlet. This should result in less effect to aquatic habitat and riparian vegetation.

Sulfate Constraints and Operational Plan

<u>General</u>

The Pelican Lake alternatives include operational plans with a range of pumping capacities and operational constraints - including no constraints. Constraints pertain to limitations on pumping capacity/volume for both high and low flow conditions on the Sheyenne River. For high flow conditions, limitations were placed on pumping so as to not exceed downstream, Upper Sheyenne River, channel capacity (i.e., 600 cfs). For low flow conditions, limitations were imposed on pumping volume so as to not exceed water quality standards at the insertion point on the Sheyenne River (e.g., 450 mg/l SO4). Based on detailed simulations and study, the best overall Pelican Lake outlet plan (in terms of hydrologic effectiveness and minimum water quality exceedances) is an outlet that has a pumping capacity of 300 cfs, constrained for 600-cfs channel capacity and 300-mg/l sulfate concentration. With the Dry Lake Diversion feature of this alternative, this plan will reduce the peak lake level under the wet future scenario from an elevation of 1460.59 feet msl for without-project conditions to 1457.5 feet msl for with-project conditions (i.e., a reduction of 3.1 feet).

Outlet Effectiveness Sensitivity to Pumping Constraints

Various pumping constraint options were studied. Figure 5-34 shows the effectiveness in terms of reduced lake level for the constraints that were studied. This figure shows that effectiveness is constant for the wet future scenario for sulfate concentrations from 450 mg/l to 300 mg/l but then begins to decline with lower sulfate constraints. The moderate scenarios show steady declines in peak lake level reduction below 450 mg/l. Figures 5-35 through 5-37 show the degree to which outlet operations are constrained by the different sulfate constraints for the wet and moderate scenarios. Based on these relationships, a sulfate constraint of 300 mg/l was selected for further investigation. For comparison, Figures 5-38 through 5-40 show elevation plots for the Pelican Lake outlet for each hydrologic scenario and for sulfate constraints of 450 mg/l and 300 mg/l along with a no-pumping project scenario. Comparison of downstream TDS levels are provided in the following water quality sensitivity discussion and further information on other water quality parameters is provided in Appendix A.

Water Quality Sensitivity to Sulfate Constraints

In the Wet Scenario, constraining operations at 300 mg/l sulfate rather than 450 mg/l makes very little difference at all downstream locations until the later (dry) years. Because of the abundance of high quality upper basin water, the 450-mg/l sulfate limitation is rarely encountered. The relative Total Dissolved Solid (TDS) concentration effect at Valley City is illustrated on Figure 5-41.

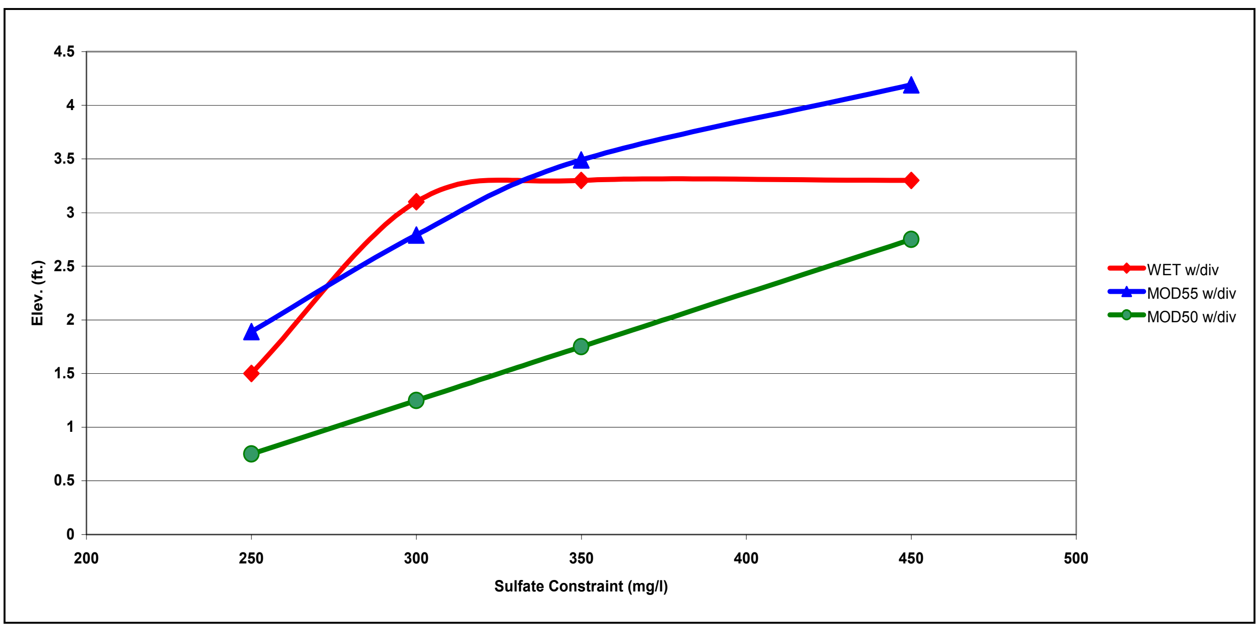


Figure 5-34: Peak Elevation Reduction as a Function of mg/l Constraint

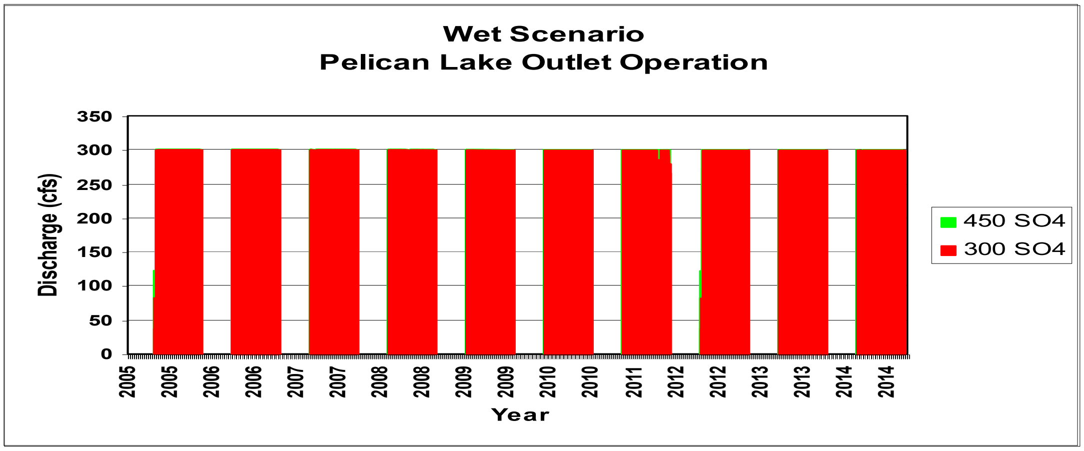


Figure 5-35: Effect of Pumping Constraints, Wet Scenario

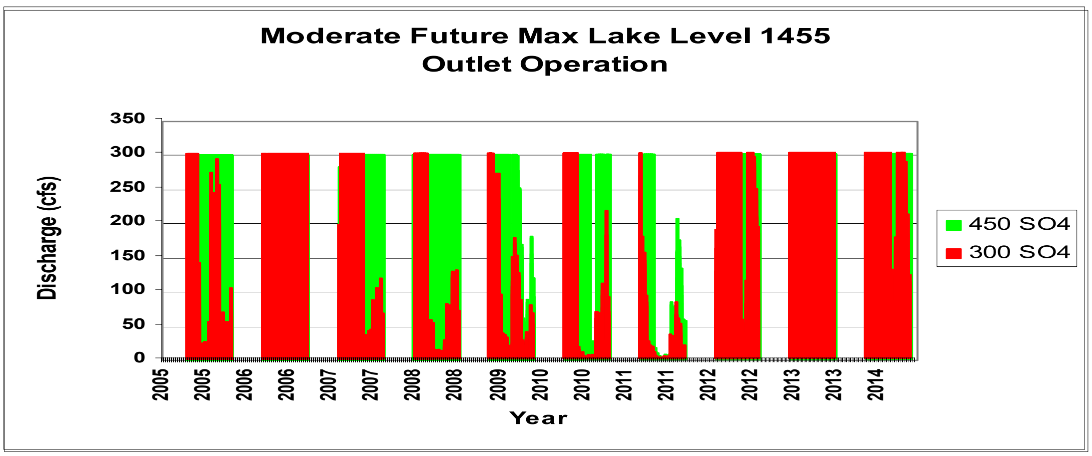


Figure 5-36: Effect of Pumping Constraints, Moderate Future Maximum Lake Level 1455

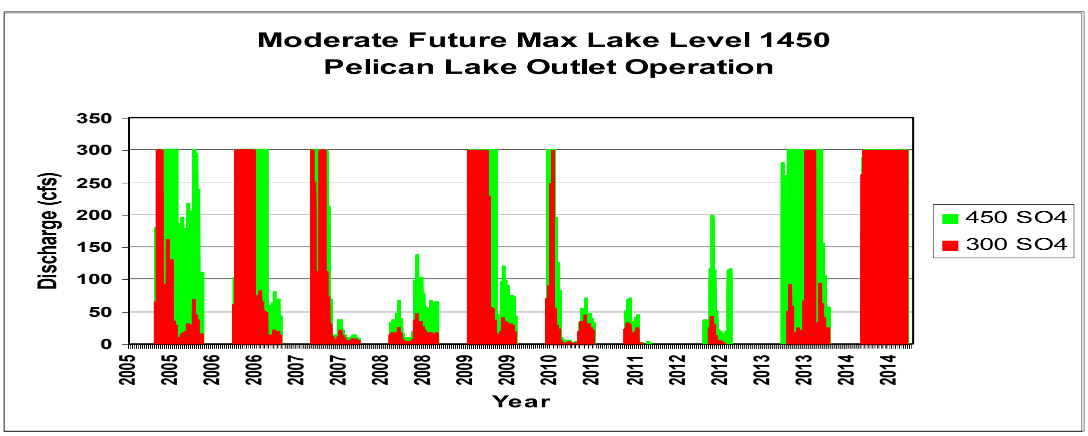


Figure 5-37: Effect of Pumping Constraints, Moderate Future Maximum Lake Level 1450

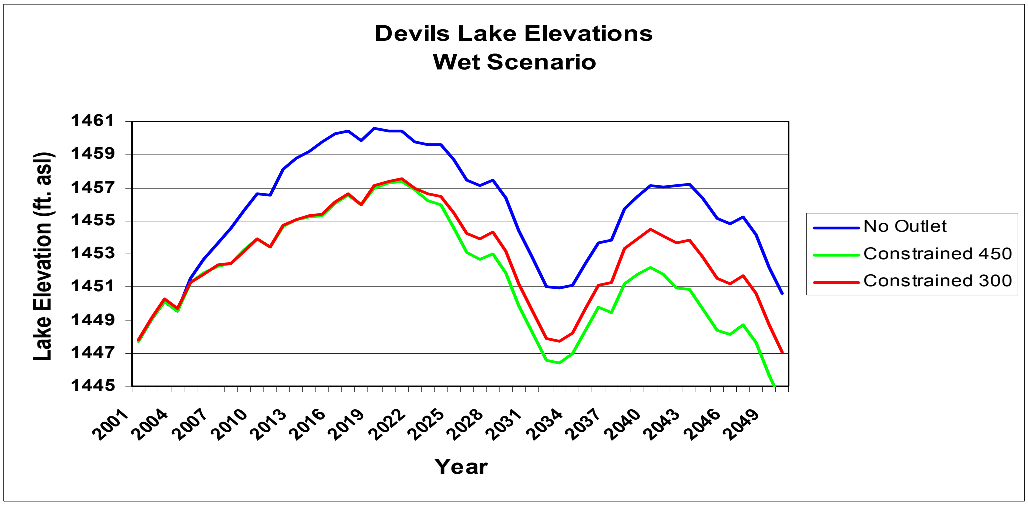


Figure 5-38: Elevation Plot, Pelican Lake Outlet, Wet Scenario

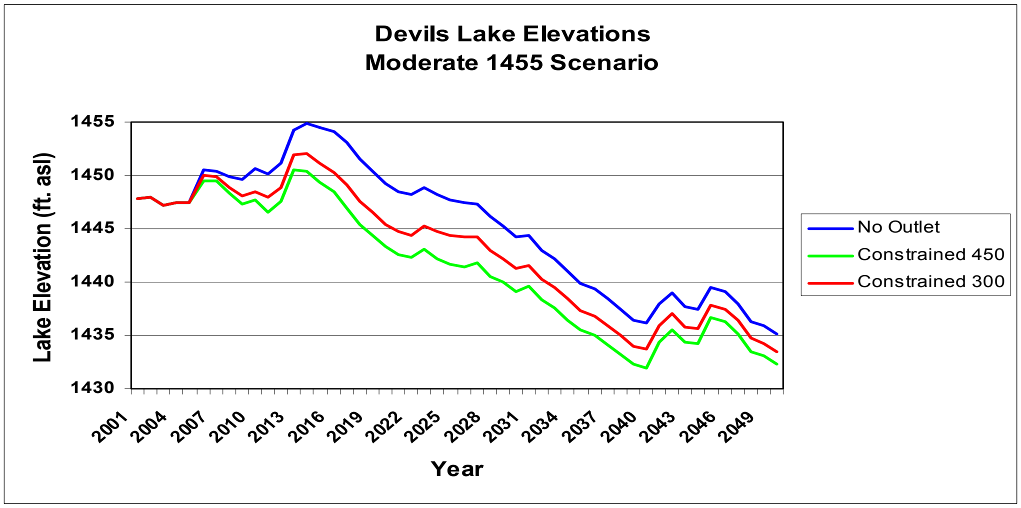


Figure 5-39: Elevation Plot, Pelican Lake Outlet, Moderate 1455 Scenario

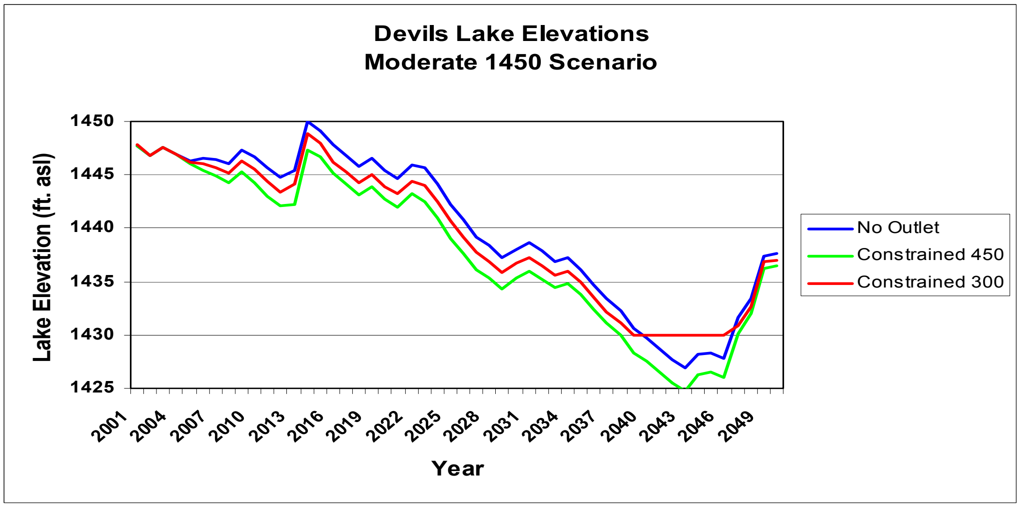


Figure 5-40: Elevation Plot, Pelican Lake Outlet, Moderate 1450 Scenario

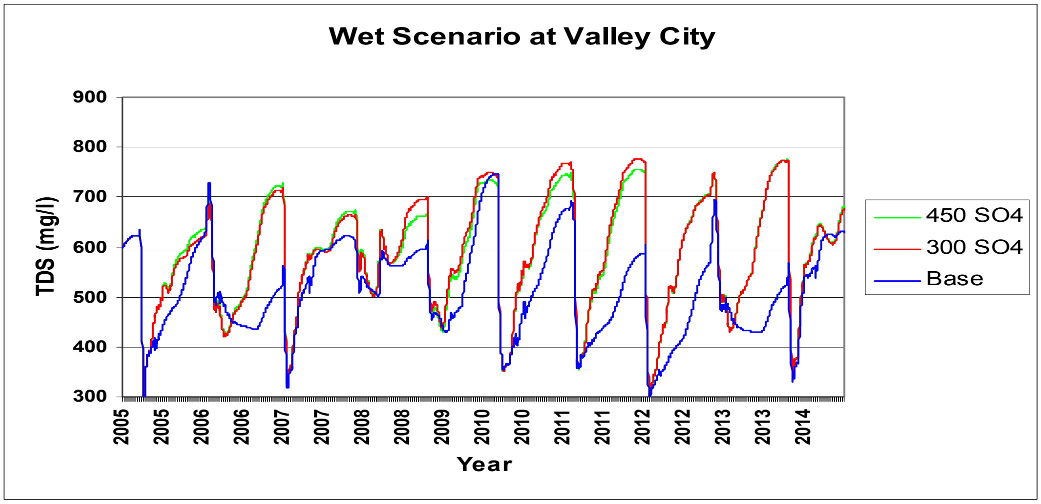


Figure 5-41: Relative TDS Concentration Effect at Valley City, Wet Scenario

In the less wet scenarios, the 300-mg/l sulfate constraint is frequently encountered during dry periods because the supply of relatively fresh upper basin water becomes depleted and some of the saltier Devils Lake water gets drawn into Pelican Lake. In the Moderate 1455 Scenario, the 300-mg/l sulfate constraint significantly reduces TDS and sulfate concentration peaks and reduces the frequency of exceedance of water quality standards relative to operations constrained at 450 sulfate. On the Red River at Emerson, Manitoba the percent of time that the 500-mg/l TDS objective is exceeded is reduced from 16 percent to 13 percent (base condition 11 percent). Figure 5-42 shows that the TDS concentrations at Valley City.

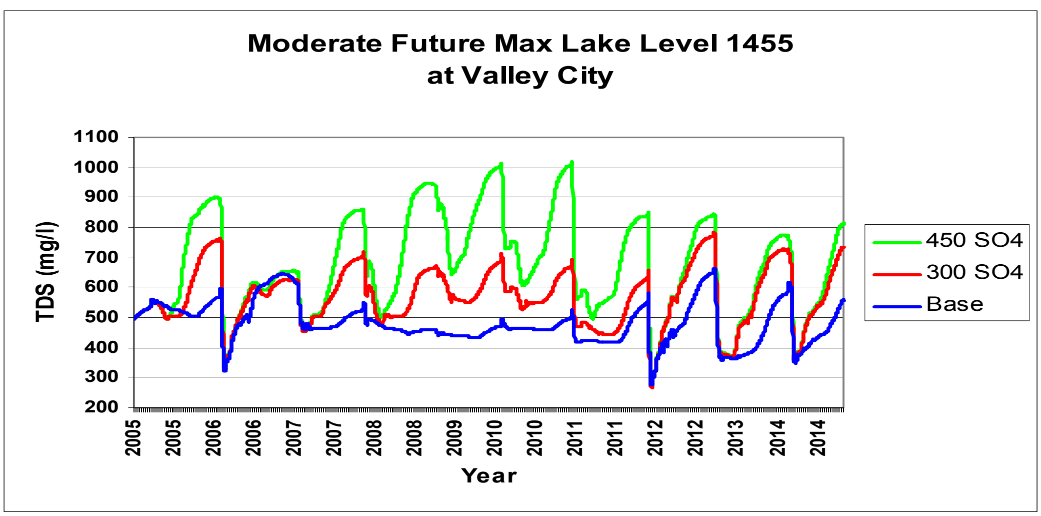


Figure 5-42: Relative TDS concentration Effect at Valley City, Moderate Future Maximum Lake Level 1455

Consideration of Systemic Operating Strategies to Reduce Water Quality Effects

TDS concentrations on the Red River of the North, under existing conditions, vary around the 500-mg/l TDS objective. The variability at any given location is driven by a combination of locally and systemically variable hydrologic conditions. Short-term (peaking) variability is driven largely by passing weather fronts. Longer-term variability is related to the changing seasons. The Corps of Engineers operates dams on several of the tributary streams, which affects TDS variability. Some of the streams are naturally more saline than others. As flow conditions change, the waters combine in continually varying proportions. Orwell Dam on the Ottertail River, a tributary to the Red River of the North, regulates a relatively fresh water source. The Lake Traverse project on the Bois de Sioux River, a tributary to the Red River of the North, regulates water with TDS and sulfate concentrations similar to Devils Lake West Bay. Baldhill Dam on the Sheyenne River regulates a major tributary with a natural TDS condition that is often greater than 600 mg/l. Additionally, there are several very high TDS sources that contribute near the Canadian border that are not regulated.

The ideal systemic operating plan for minimizing TDS levels is one in which all dam gate and pump operations could be coordinated to release discrete masses of water such that they would intercept or avoid each other to achieve the desired dilutions downstream. Such accurate operation would require *perfect knowledge* of the course, speed, and water quality of multiple sources of water on a real-time basis. The biggest problem with this is that time of travel from the various gates to the target locations is on the order of several days to several weeks. Local transient events, (i.e., storm events or extended dry periods) are unpredictable in that time frame. Less ideally, however more realistically, we would have to settle for a *general expectation* rather than *perfect knowledge* that there will be targets downstream in three or four weeks.

The options for manipulating gates at Orwell, Traverse, and Baldhill Dam are extremely limited. They must be operated for their authorized project purposes. Orwell reservoir is too small to provide significant conservation storage. Lake Traverse is a high TDS source and has a long history of causing hardness and other water quality problems at the Fargo, North Dakota, and Moorhead, Minnesota, water utilities. The issues surrounding such a comprehensive operational strategy are complex. In the past, operational strategies have been tested and compromises made; however, it is anticipated that any further change would likely stimulate additional controversy.

With outlet operations, Lake Ashtabula (Baldhill Dam) becomes up to 80 percent Devils Lake water by late summer each year. Under the existing operating plan for the Baldhill Dam, the reservoir must be drawn down for flood control storage each winter. These high seasonal flows from the Sheyenne River contribute significantly to high TDS conditions on the Red River of the North during fall and winter months. It may not be feasible to target fall and winter exceedances very effectively (i.e., by withholding discharges from Baldhill Dam) without reducing outlet pumping or compromising flood protection for Valley City.
Outlet operations could be scheduled, however, to affect reduced flows on the lower

Sheyenne River in the fall; however, a 3- to 4-week delay to allow for hydraulic travel time would have to be built into this plan. To examine the efficacy of such a strategy, two scenarios (i.e., Wet, and Moderate 1455) were run with the HEC-5Q model in which outlet pumping was discontinued during August of each year with the expectation that TDS conditions on the Red River in September might be improved. Figure 5-43 presents the count of all exceedance days sorted by months for the first 10 years of outlet operation under the Wet Scenario. The "No Aug" strategy appears to significantly reduce the number of exceedances not only in September, but in the next 4 months as well. The total number of exceedances was reduced from 373 to 279 (base condition 129).

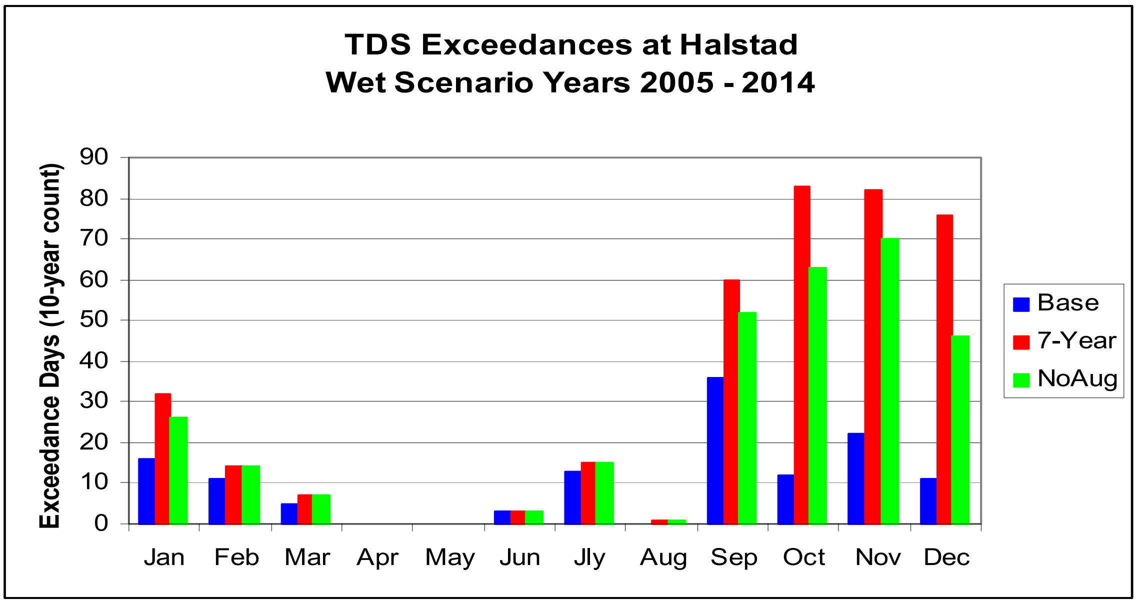


Figure 5-43: TDS Exceedances at Halstad, Wet Scenario

In the Moderate 1455 Scenario (Figure 5-44), the "NoAug"strategy was considerably less effective in terms of exceedance counting. Concentration reductions were achieved (not shown) but usually not enough to get below 500 mg/l. The poor performance is mostly due to the fact that critical conditions on the Red River occurred during relatively dry years when August pumping was already reduced by the sulfate constraint so that shutting of the pumps in August would not significantly reduce flow on the lower Sheyenne River in September.

In terms of effect on lake stages with the "NoAug" strategy in place, peak Devils Lake levels under the Wet Scenario were 1458.2 feet for the "NoAug" strategy, rather than 1457.5 feet for the full 7-month outlet operation.

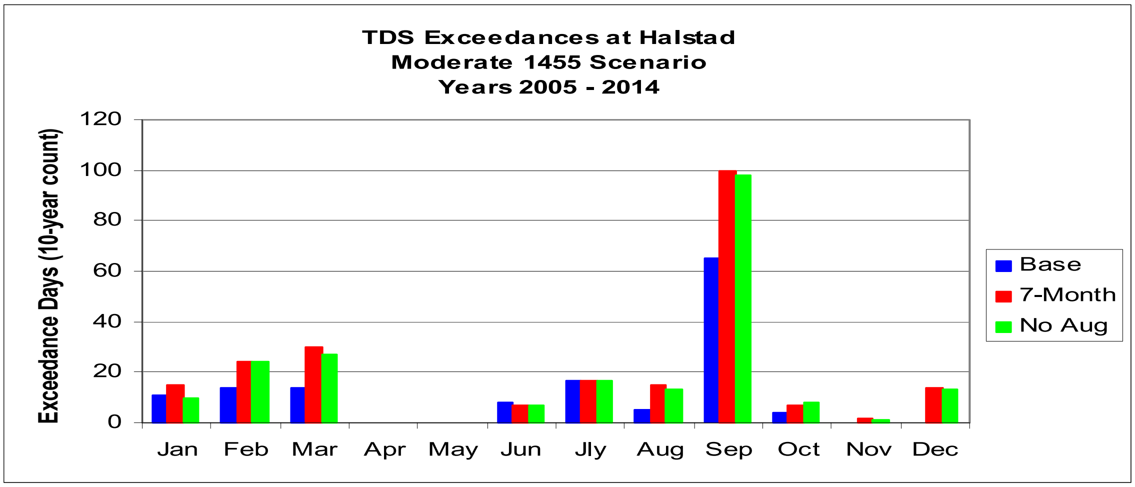


Figure 5-44: TDS Exceedances at Hadstad, Moderate Scenario

The "NoAug" scenarios were examined and presented here as an example of how various real-time operational strategies may be effective in improving downstream water quality conditions. The exercise also confirms that there probably is no strategy that would eliminate all exceedances of water quality standards and that effective water quality improvement generally comes at the expense of outlet effectiveness. For the purpose of this report, it is assumed that such a reduction in outlet effectiveness would not be acceptable and is therefore not reflected in the selected operating plan. However, it should be noted that it would be most appropriate, in the context of adaptive management and interagency collaboration, to pursue operational strategies in the future that would reduce the number of water quality exceedances while not significantly reducing the effectiveness of the outlet.

<u>Consideration of an Operating Strategy Based on Constraining Operations Each Year Dependent on the Spring Inflow Forecast</u>

All of the operational simulations described previously in this report assume that the outlet would operate up to the 300 cfs maximum discharge from year to year to achieve a lake draw-down objective regardless of expected spring runoff. Reviewers of the Draft EIS suggested that operating from year to year constrained by an expected runoff criteria might be effective and reduce downstream water quality effects. To evaluate that three scenarios were run: Wet, Moderate 1455, and Moderate 1450, in which the pumping rate would be constrained to 200 cfs in any year with a spring forecast inflow of less than 60,000 acre-feet, a volume that represents about one half foot on the lake at the current level. The model simulations indicated that there would be only very slight differences in outlet effectiveness and downstream water quality effects during the first ten years of operation. In the Wet Scenario only one of the first ten years would be dry enough to trigger the constraint. In the moderate scenarios operations would become so limited by the 300 mg/l sulfate constraint that the forecast criterion would be for the most part irrelevant.

Sensitivity of Outlet Effectiveness and Water Quality Effects to Ramped Outlet Operations

All of the operational simulations described previously in this report assume that daily discharge changes would be made in the full measure proscribed by the channel capacity and water quality constraints. In reality the discharges would be ramped up and ramped down over periods of several days to protect aquatic organisms that need time to adapt to changing flow conditions. To evaluate the sensitivity of outlet effectiveness and water quality effects to ramped operations simulations were run of the Wet Scenario, Moderate 1455, and Moderate 1450 in which daily outlet discharges were increased by not more than 50 cfs per day and were not decreased by more than 25 cfs per day. The simulations indicated that there would be insignificant differences in operational effectiveness and downstream water quality effects because relatively small quantities of water would be affected by ramping.

Dry Lake Diversion Incremental Justification

To improve the effectiveness of the Pelican Lake outlet plan with a 300-cfs pumping capacity and 300-mg/l sulfate constraint (shown in the previous section to be the most effective plan with minimal water quality impact), the Corps analyzed a diversion feature from Dry Lake. The Dry Lake Diversion feature modifies the operation of the existing Dry Lake-Channel A project and, in conjunction with other project features, restores a portion of the historic flow of fresh water from Dry Lake to Pelican Lake via Big Coulee.

Modeling done by the USGS showed that 80 percent of the total volume that could be conveyed to Big Coulee could be accomplished with a 500-cfs diversion. A diversion with larger capacity did not appear to justify the increase in costs and environmental impacts for the effectiveness gained. As part of the sensitivity analysis, the Corps requested that the USGS make some simulations using a maximum diversion discharge of 500 cfs. Flows up to 500 cfs were diverted through the Dry Lake Diversion regardless of the flow rate in Big Coulee. Flows out of Dry Lake in excess of 500 cfs were then diverted through the Channel A diversion. The sensitivity runs were made for a 300-cfs pumping capacity, a range of sulfate constraint values, three hydrologic scenarios, and with and without the diversion feature. Figure 5-45 shows the results of these runs.

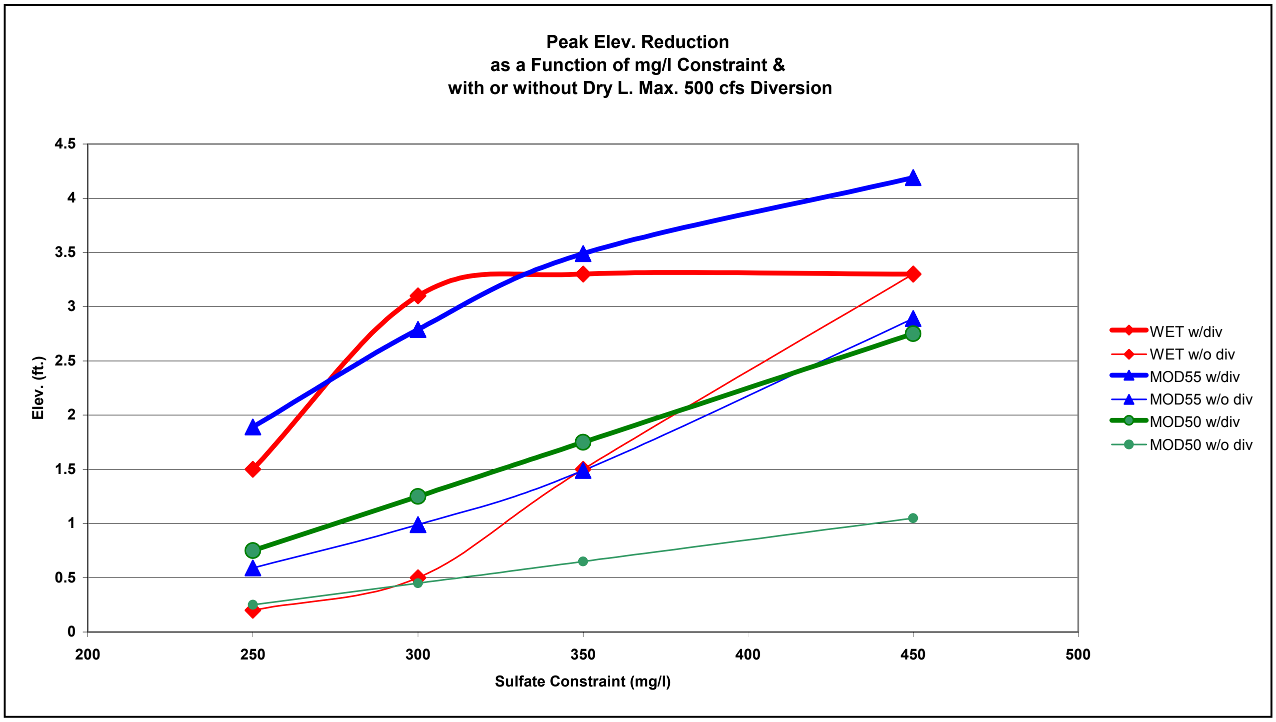


Figure 5-45: Results of Sensitivity Runs, with or without Dry Lake Diversion

The adopted plan is the Pelican Lake 300-cfs pumping capacity, constrained for 300 mg/l sulfate. Without a diversion, the reduction for the wet future is only 0.5 foot, but with the diversion, the reduction is 3.1 feet in stage on Devils Lake. The diversion cost is estimated at approximately $10 million. If no diversion were adopted, the equivalent stage reduction could be achieved only by increasing the water quality constraint to 450 mg/l SO4. However, this option would increase water quality exceedances downstream. Therefore, the $10-million diversion feature not only improves the hydrologic effectiveness of this alternative, but also helps to minimize downstream water quality exceedances.

Table 5-17 shows the economic results of the incremental analysis of including the Dry Lake Diversion with the Pelican Lake outlet. The associated Pelican Lake outlet has a pumping capacity of 300 cfs, constrained for 300 mg/l SO4 (PL300/300). For the stochastic analysis and three future scenarios, the benefit-cost ratio is above unity, ranging from 1.02 to 12.31. The analysis shows that the diversion is an economically justified feature of the outlet alternative. Appendix A documents this analysis in more detail.

Table 5-17: Dry Lake Diversion Economic Analysis

Analysis Type or Future Scenario	Total Cost	Lake Level Without Diversion	Lake Level With Diversion	Total Annual Benefits	Total Annual Net Benefits	BCR
Stochastic	$9,068	1456.9[1]	1455.85[1]	$704	$15	1.02
Wet Future	$9,068	1460.1	1457.5	$12,050	$11,071	12.31
Moderate 1455 Future	$9,068	1453.9	1452.1	$1,917	$1,131	2.44
Moderate 1450 Future	$9,068	1449.6	1448.9	$1,225	$516	1.73

Note: All Costs are in Thousands of Dollars.

[1] Elevation based on 10% probability of reaching or exceeding given lake level in 50 years.

ASSESSMENT OF ALTERNATIVES TO MEET PROJECT OBJECTIVES

Intangible Considerations

Recognizing the many considerations associated with the alternatives evaluation, Table 5-18 has been prepared in an attempt to summarize the somewhat more intangible aspects of developing a recommendation.

The categories of considerations are first divided between the Devils Lake area and the downstream area. A number of the potential solutions for flooding at Devils Lake have completely opposite sets of impacts and viewpoints from these two areas, a common situation with most water resource projects. For the Devils Lake area, the categories identified are social effectiveness, environmental impact, Tribal issues (in connection with the Fort Totten Indian Reservation), and acceptability/implementability. For the downstream area, the areas of consideration are social impacts, environmental impacts, the ability to reduce the risk of a natural overflow, and acceptability/implementability.

General Conclusions

The analysis accomplished for this evaluation of alternatives shows that selection of an alternative is highly dependent on assumptions made with respect to future lake levels. Using the results of the stochastic modeling approach for the economic analysis, the only cost-effective alternative appears to be the continuation of infrastructure measures within the Devils Lake basin, including measures for further flood protection and continued transportation needs. If a wet future is assumed to occur, the outlet plans are shown to be the most cost-effective alternatives for addressing the damages associated with rising water levels at Devils Lake.

Table 5-18: Matrix of Alternatives – Other Considerations

	Devils Lake Area				Downstream Area			
	Social Impacts	Environmental Impacts	Tribal Issues	Acceptability/ Implementable?	Social Impacts	Environmental Impacts	Reduce Risk of Natural Overflow?	Acceptability/ Implementable?
Alternatives within the Basin								
Upper Basin Storage	Landowner opposition	Minimal	Minimal	Some oposition	No impact	No impact	Minor	Yes
Expanded Infrastructure Protection	Additional area protected from flooding	Minimal	Portion of reservation protected	Yes, but does not stop lake rise	No impact	No impact	No	Yes
Raise Natural Outlet	Unacceptable	Significant	Unacceptable	Strong opposition	No impact	No impact	Significantly	Yes
Outlet Alternatives								
West Bay Outlet (300 cfs) (Peterson Coulee)	Minimal stage reduction	Minor adverse WQ in lake	Portion of outlet on reservation lands	Yes	Some flooding, erosion, WQ	Significant	Moderately	Mostly opposition
West Bay Outlet (480 cfs) (Peterson Coulee)	Most effective stage reduction	Moderate adverse WQ in lake	Portion of outlet on reservation lands	Yes	More signif. Flooding ersosion, WQ	Very Significant	Significantly	Strong opposition
Pelican Lake Outlet (300 cfs)	Moderate stage reduction	Minor adverse WQ in lake	Water Quality in lake	Yes	Some flooding, erosion, WQ	Significant	Moderately	Mostly opposition
Pelican Lake Outlet (480 cfs)	Most effective stage reduction	Moderate adverse WQ in lake	Water Quality in lake	High Cost & In-Lake WQ at Issue	More signif. Flooding erosion, WQ	Very Significant	Significantly	Strong opposition
Pelican Lake Bypass (480 cfs)/PL2	More effective stage reduction	More adverse WQ in lake	Water Quality in lake	High Cost & In-Lake WQ at Issue	Moderate flooding, erosion, WQ	Moderate	Significantly	Moderate opposition
Pelican Lake Bypass (480 cfs)/PL3	More effective stage reduction	More adverse WQ in lake	Water Quality in lake	High Cost & In-Lake WQ at Issue	Moderate flooding, erosion, WQ	Moderate	Significantly	Moderate opposition
East End Outlet	Most effective stage reduction	Improved WQ in lake	Preferred Plan	Preferred	Significant impacts	Very Significant	Significantly	Very strong opposition
Combination Alternatives								
Combination 1 (UBS, EIP)	Minimal impact, but minimal effectiveness	Minimal	Minimal	Some opposition	No impact	No impact	No	Yes
Combin. 2 (UBS, EIP, Peterson/300)	Minimal stg.reduction, but other protect.	Moderate adverse WQ in lake	Portion of outlet on reservation lands	Yes?	Moderate flooding, ersosion, WQ	Moderate	Moderately	Mostly opposition
Continued Infrastructure Protection (this is the "likely future" base condition, as measured against no action)	Protection, but no stage reduction	Minimal	Protection, but no stage reduction	Funding and local acceptance problems	No impact	No impact	No	Yes

Notes:
- As measured against the base condition (continued emergency measures)
- The word "significant" is used as a term of comparativety in the table and is not used in the same context as "significant" under NEPA

Both approaches have their strengths and weaknesses. The stochastic model provides a means of conducting a probability weighted economic analysis. While the use of a wet future scenario may provide insight into potential benefits of the outlet alternatives, such an analysis provides little assurance as to the soundness of such an investment, since it is tied to the unlikely assumption that a particular scenario will ever occur. Studies indicate that an outlet plan using methods that would determine expected net benefits by producing probability-weighted benefits and costs would not be economically justified. Within the context of this evaluation, the preferred action in the near term would be the continuation of infrastructure protection.

Departing from stochastic-based methods and using a cost-effectiveness analysis with the scenario of a future without-project condition of a repeated wet cycle (a non-probabilistic analysis) indicates a Pelican Lake 300-cfs outlet plan would be the overall best outlet alternative. It is among the best outlet alternatives for maximizing net benefits for the stochastic and wet future scenario approaches. This outlet alternative maximizes net benefits for both the 1455 and 1450 moderate scenarios and is among the best of the outlet designs for minimizing downstream water quality impacts.

SUMMARY OF ALTERNATIVES SELECTED FOR MORE DETAILED ANALYSIS

From the Intermediate Array of alternatives, the alternatives that address the planning objectives and have the most likelihood of implementation were carried forward for more detailed analysis. Following is a summary of the outcome of the selection process. The final cost estimates for the alternatives that will be carried forward for the detailed evaluation vary from the estimates used in the preceding alternative screening, since the final cost estimates (and resulting Benefit-Cost Ratios) are developed with a greater level of detail.

Most Likely Future Without Project (Infrastructure Protection Plan)

This is the base condition, against which other alternatives are compared. **Carry forward for more detailed analysis.**

Outlets

The 300-cfs outlet plan constrained for downstream channel capacity and sulfate levels was selected as the best of the outlet alternatives because it provides the ability to operate and minimize the number of times that downstream water quality standards on the Red River are exceeded while providing as much effectiveness as possible in reducing lake levels. As described previously in the sensitivity analysis section **Sulfate Constraints and Operational Plan**, an outlet with a 300-mg/l constraint for SO_4 can be provided using a Pelican Lake alignment with little change in effectiveness under the Wet Scenario versus the plan with a 450-mg/l constraint. Based on this information and on the discussion in the General Conclusions above, **the Pelican Lake 300-cfs outlet** with a

300-mg/l constraint for water quality should be carried forward for more detailed analysis.

Raise Natural Outlet

This alternative was dropped from the study because it does not address flooding in the Devils Lake Basin and does not have positive net benefits.

Upper Basin Storage

Although the effectiveness of this alternative was shown to be minimal in the evaluation of the Intermediate Array of alternatives, it still retains much interest from many stakeholders. **Carry forward for more detailed analysis**.

Expanded Infrastructure Protection

This alternative was shown to have positive net economic benefits based on the analysis performed for the Intermediate Evaluation. **Carry forward for more detailed analysis.**

DESCRIPTION OF ALTERNATIVES TO BE EVALUATED IN DETAIL

Four alternatives were carried forward from the intermediate array of alternatives. Additional design and study were performed in order to better define the alternatives, their costs and economic benefits, and their impacts.

Most Likely Future Without Project (Infrastructure Protection Plan)

Introduction

Scope

As previously stated, the most likely future without-project condition is the continuation of infrastructure protection measures similar to what have been constructed in the recent past. However, in an attempt to more fully define this future without-project condition, a more advanced analysis of the 24 previously identified infrastructure features around the lake was performed by Barr Engineering in order to better identify the most economical flood protection measures. The study used previous work described in the section "Intermediate Alternatives" and in Appendix B as its base. The study reexamined the previous work to better identify significant areas and structures needing protection, and evaluate in greater detail the costs and benefits of flood protection measures that would need to be implemented. Because the expected actions at higher lake levels are more uncertain and are not of imminent concern, the study focused on performing detailed analysis only on the first flooding-related actions that would be needed before the lake reached elevation 1454 feet msl. For lake levels greater than 1454, flood damages and protection for infrastructure were evaluated at a similar level of detail as the previous analysis. The remaining flood damages and protection for structures up to elevation 1463 feet msl were evaluated at a level of detail similar to the previous analysis.

Recommended Features

Two of the infrastructure features have had planning and analysis carried to a much higher level of detail than the others. This study shows that both of these features have positive net benefits. For Feature 2, the City of Devils Lake, the next levee raise has been extensively developed and Plans and Specifications are currently being prepared for this feature. In addition, an Environmental Assessment, a Micro Computer Aided Cost Engineering System (MCACES) cost estimate, and a Gross Appraisal of Real Estate have been completed for this feature, allowing it to be recommended as a Federal flood control project. The planning for this project is summarized in a report titled *City of Devils Lake Alternative Alignment Study.* A study of Feature 16, US Highway 281, south of US Highway 2, has been performed by the North Dakota Department of Transportation and is nearing completion as well.

Following is a summary of the most recent study and its results. For more details on how the study was performed and the results of the study, please refer to the report titled *Devils Lake Infrastructure Protection Study, January 2003* by Barr Engineering.

Devils Lake Features Analyzed

The analysis performed during the recent study was focused on the features that would require action in the near future. Sixteen features were identified that would require some sort of flood protection action at lake levels below 1454. The 24 previously identified features are listed below (also shown on Figure 5-3); the 16 features identified for additional analysis are shown in bold text. All of the features are described and shown in Appendix E, Devils Lake Infrastructure, General Information.

1. **Churchs Ferry**
2. **City of Devils Lake**
3. **Fort Totten**
4. **City of Minnewaukan**
5. **St. Michael**
6. **Gilbert C. Grafton Military Reservation**
7. **Grahams Island State Park**
8. **Rural Areas**
9. Red River Valley and Western Railroad
10. **Canadian Pacific Railroad**
11. **Burlington Northern Railroad (Along US Highway 2)**
12. Burlington Northern Railroad (Churchs Ferry to Cando)
13. US Highway 2
14. ND Highway 57 (between ND Highway 20 and BIA Highway 1)
15. ND Highway 57 (between BIA Highway 1 and US Highway 281)
16. **US Highway 281 (South of US Highway 2)**

17. US Highway 281 (North of US Highway 2)
18. ND Highway 19
19. ND Highway 1
20. ND Highway 20 (North of City of Devils Lake)
21. ND Highway 20 (City of Devils Lake Dike to ND Highway 57)
22. ND Highway 20 (ND Highway 57 to Tokio)
23. BIA Highway 1
24. BIA Highway 6

Scope of the Additional Analysis

For the 16 features identified as needing action in the near future, a more detailed and comprehensive examination of various flood protection measures and their comparative costs was made, at the first action level. The more detailed analysis was done to provide an updated and more accurate appraisal of both the costs and benefits of providing flood protection for the 16 features. The study took into account environmental costs, geological and geotechnical considerations, local hydrology and its effects on providing flood protection, and gave a more uniform assessment of the costs for planning and design, supervision and administration, and operations and maintenance. It also included a more detailed examination of costs related to real estate acquisition, and refined the determination of unit costs for construction materials.

The study identified potential Hazardous, Toxic, Radioactive Waste (HTRW) sites, cultural sites, and environmental resources in the project areas. Existing information was used to perform this portion of the study, as time did not allow field surveys to be conducted.

Flood damages were also examined in more detail for the 16 features. Potential flood-related damages to roads, railways, and structures (including residential, commercial, and park buildings, as well as some community infrastructure) were reassessed, and the listings of flood-related damages were updated to more accurately reflect the situation in 2002. The study identified the lake elevations at which the features would actually suffer flood-related damages.

The lake levels at which cost and damages would be incurred was reevaluated. Assessments were provided as to the time that would be required for planning and design, and for construction of the flood control measures for each of the features. These times were used in conjunction with the probability of lake level rises during these times in order to identify lake levels at which flood protection activities must commence, and when they must be completed.

For more details of the analysis for each feature, please refer to the report *Devils Lake Infrastructure Protection Study, January 2003.*

Extent of Detailed Analysis

Although the new analysis focused on the first action level for infrastructure features that would be impacted at lake elevations below 1454 feet msl, for some features, actions that might be taken at higher levels influence what is the best solution for action at the first action level. The features were therefore sorted into Single Action Level Features that required a focus only on the first increment of protection, and Multiple Action Level Features that required analysis throughout all possible lake levels.

Single Action Level Features

Of the original list of 24 features, 16 had action levels in the specified range for inclusion in the more detailed study. Of those 16 features, 13 were seen to have only one available strategy (among the strategies analyzed previously) for flood protection. For these features, the first increment of flood protection (flood protection performed at the first action level) could be analyzed independently of successive protection increments that would be required for lake levels above 1454. Therefore, the study only performed detailed analysis of the first action level. For an analysis of the infrastructure protection around Devils Lake as a whole, the action levels at higher lake levels were evaluated, too, but at a lower level of detail. The single action level features are listed below:

Single Action Level Features	
Feature Number	**Feature Name**
1	Churchs Ferry
2	City of Devils Lake
6	Gilbert C. Grafton State Military Reservation
7	Grahams Island State Park
8	Rural Areas
10	Canadian Pacific Railroad
11	Burlington Northern Railroad (along US Highway 2)
16	US Highway 281 (South of US Highway 2)
17	US Highway 281 (North of US Highway 2)
19	ND Highway 1
22	ND Highway 20 (ND Highway 57 to Tokio)
23	BIA Highway 1
24	BIA Highway 6

Multiple Action Level Features

Three of the sixteen features had multiple flood protection strategies that were considered viable. By contrast to the single action level features, for these three features it was also necessary to analyze the effects of decisions made at action levels above 1454 in order to determine the most economical action at the first action level. Analysis of these three features entailed a comparison of the net benefits of each available strategy so as to determine which had the largest net benefits. That strategy was then analyzed further to determine the net benefits of proceeding with flood protection measures at just the first action level – as was done with the single action-level features. The multiple action-level features are listed below:

Multiple Action Level Features	
Feature Number	**Feature Name**
3	Fort Totten
4	Minnewaukan
5	St. Michael

Lake Levels and Flood Protection Decisions

The decision-making process for flood protection was analyzed as it relates to rising lake levels. For decisions regarding flood protection, five elevations can be important, depending on the flood protection situation at the feature being considered. These decision-critical elevations are described in the following sections. These elevations were used to determine the lake levels at which costs and damages are incurred at the yearly time steps for which lake levels are computed in the economics model. They also provide trigger elevations at which projects should be initiated.

Low Structure Elevation

The low structure elevation is the elevation of the lowest point on a structure (building, highway, railway, levee, etc.) at which water-induced damage would occur. This elevation must be identified in order to make decisions regarding flood protection for the structure.

In most cases, the low structure elevation is that of the lowest element of the feature. For a group of homes, for example, the low structure elevation is taken as the ground elevation at the lowest home in the group. For railroads, highways, and levees, it will be the lowest point on the top of the structure (top of levee, roadway surface, top of rail) for the section in consideration.

Lake Damage Elevation

At some lake elevation, water damage to the structure will begin to occur. The lake damage elevation can generally be expected to be lower than the low structure elevation. This is because waves and wave run-up will cause damage even when the (mean) lake surface elevation is below that of the low structure elevation. In the case of roads, the damage elevation was assumed to occur when the lake is 3 feet from the top of the lowest point in the road. For the railroads, the damage elevation is assumed to be 4 feet from the top of the rail. For rural features, such as homes and farm outbuildings, damages were assumed to occur when the lake came within 1 foot of the low structure elevation.

For levees, the top of the levee is determined by adding a freeboard height above the design high water surface in order to prevent overtopping of the levee by waves. The chances of failure due to wave run-up and overtopping vary for water levels throughout the freeboard range from very, very low at the design high water surface elevation to certainty when water levels are at the levee top. For the purposes of this analysis, the lake damage elevation was assumed to occur when the lake surface level was one half of the freeboard height from the top of the levee.

Project Completion Elevation

The flood protection project should be completed before the lake level actually reaches the lake damage elevation. In most cases, this is to ensure that construction activities are not hampered by or prevented by water at the construction site. The project completion elevation will depend on the specifics of the construction considerations for the project in question (levee, road raise, etc.). It would not be greater than the lake damage elevation. For levees, it would be at the design high water surface for the levee.

Construction Initiation Elevation

Construction of the flood protection project should be completed before a feature is damaged by rising lake levels. The construction initiation elevation depends on the estimate of the time required for construction, and the probability of the lake rising to the protection level of the project within that time.

For roads, railroads, and rural features, the construction initiation elevation is assumed to occur within the same one-year analysis time step used in the economics model that the lake damage elevation occurs at. Rural features, such as homes and farm outbuildings, can be relocated quickly after the lake reached the damage elevation, which is 1 foot below the low structure elevation for this analysis. Roads and railroad embankments can also be raised reasonably quickly. And the consequences of the lake rising quickly and overtopping the road or railroad, if the rate of rise was faster than the embankment raise, are only temporary loss of use of that feature. For this reason, it is considered more economical to wait until damage is imminent for these types of features than to construct raises that may not be needed.

For the levees, if the lake level rises faster than the speed of construction, overtopping and failure of the levee will occur, which could result in very large amounts of property damages. It also has the potential for creating hazards to personal safety for those behind the levee. Based on this concern, it was determined that the goal for a Federal flood protection project should be to provide protection so that there is less than a 1-percent chance that the lake level will exceed the design elevation of the levee (top of levee minus the freeboard for wave run-up). In order to do this, the flood control project construction must begin at or below lake levels at which there is a 1-percent chance of a lake rise reaching the design level of the levees, in the length of time needed for construction. To compute this, curves were prepared of the 1-percent chance of lake rise over periods of time beginning at different starting lake elevations. Knowing the design level of the levee and the expected length of the construction period, the lake level at which construction should be initiated can be determined from these curves. The curves used are shown on Figure 5-46.

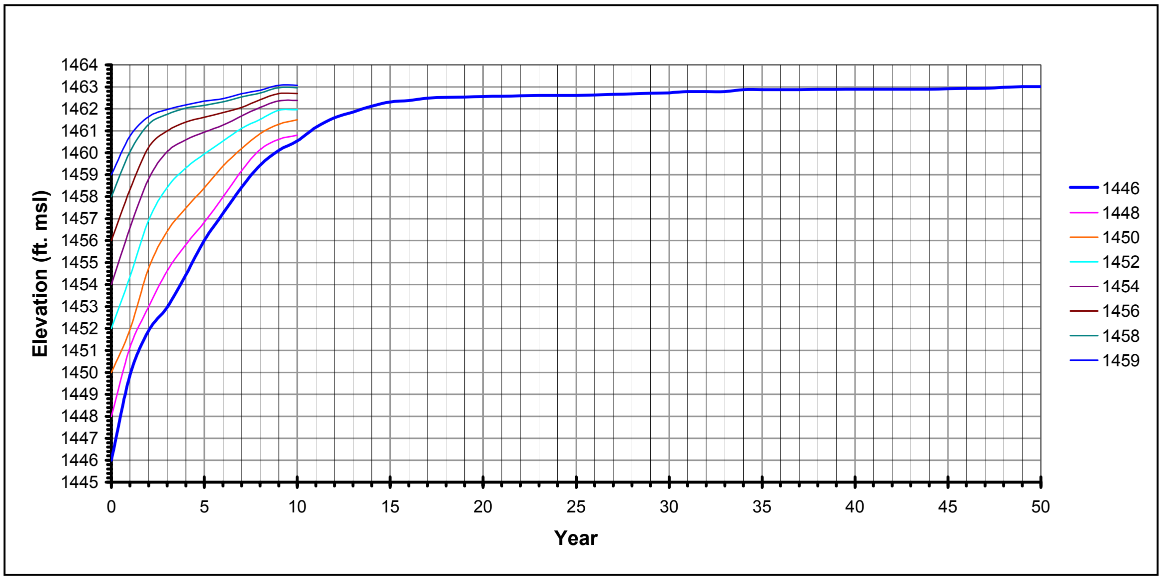


Figure 5-46: Cumulative Exceedance Levels for Devils Lake for 1 Percent Probability (Starting Water Surface Date = 01 Oct.)

Project Initiation Elevation

In order for the flood damage protection project to be completed by the time that the lake elevation reaches the project completion elevation, planning and design activities must begin at a time when the lake level is below the construction initiation level. The lake level at which planning and design activities must occur will depend on the lead time required for the particular project. The time required can be determined in a manner similar to that used to determine the Construction Initiation Elevation.

Flood Protection Actions for Individual Features

Following is a description of the flood protection measures found to be the most economically beneficial for each of the 16 features that were analyzed. More description and drawings of the individual features can be found in Appendix E, "Devils Lake Infrastructure, General Information."

Feature 1: Churchs Ferry

The Infrastructure Protection Study's analysis for Churchs Ferry considered one incremental flood protection strategy. At the first action level (lake elevation 1451 feet), relocation was the only strategy that was feasible both from an economic and a constructibility standpoint. The strategy involved relocation of three residences, a church, fire hall, City Hall, post office, repair shop, bar, school buildings, Masonic Lodge, a City shop, and a railroad maintenance building. The existing sewage lagoons serve the three residences and the remaining buildings. The single flood-protection strategy analyzed for Churchs Ferry (relocation of structures) would require action before the water rises to 1452 and overtops the sewage ponds.

Feature 2: City of Devils Lake

The most economical protection strategy for the City of Devils Lake was found to be incremental levee raises. For the incremental levee raise strategy, the existing levees need to be raised to provide continued protection of the City of Devils Lake against flooding. The lake level identified as the Construction Initiation level is 1448 feet msl for the levees with a design high water level of 1454 feet msl. Besides directly raising these levees, there are several locations where it will also be necessary to build smaller levees to connect to high ground and maintain the integrity of the levee that protects the City of Devils Lake.

A separate January 2002 study by Barr Engineering Company, entitled the *City of Devils Lake Alternative Alignment Study,* analyzed the levee tiebacks and various alternative levee alignments to raise the level of protection for the City of Devils Lake to a design lake elevation of 1454, or top of levee (TOL) elevation of 1460. These levee sections would be constructed concurrently with any future raises of the existing levees, unless an alternative alignment is selected for construction. Plans and specifications for the levee raises of the Stage 1A, Stage 2A, tiebacks, and baseline alignments are scheduled for completion in the spring of 2003.

Feature 3: Fort Totten

Flood protection options considered for Fort Totten included the following:

1. Construction of levees to protect structures along the northeast side of Fort Totten. Construction of the levees would also include relocation of one isolated structure. Extending the levee to protect this house would require an additional 500 feet of levee.

2. Relocation of the affected residences.

3. Relocation of the Sullys Hill National Game Preserve structures.

The levee option was found to be very expensive relative to the property that it protects, and would require the operation and maintenance of a permanent pumping station. The most economical strategy is relocation of affected structures. The work at the first action level would be to relocate one residence and all of the Sullys Hill facilities and Sullys Hill access road at a lake elevation of 1448 feet msl.

F*eature 4: City of Minnewaukan*

Flood protection options considered for the City of Minnewaukan included the following:

1. Construction of levees to protect the City of Minnewaukan. The levees would tie into high ground near the reroute location for US Highway 281 (South of US Highway 2), and would allow access to the city through the existing roadway system. Construction of the levees would also include relocation of isolated structures, such as the county fairground buildings and a few isolated structures in the levee footprint.

2. Relocation of all affected structures (including the homes severed from the main land).

The most economical flood protection strategy for Minnewaukan is incremental levee protection. At the first action level, the construction initiation lake level would be1451 feet for levees with a top of levee elevation of 1460 feet msl and the design protection level would be 1456 feet msl. A permanent pumping station would also be constructed. A few structures exist below elevation 1451 that would require protection by emergency levees or relocation at lake levels below 1451.

Feature 5: St. Michael

Flood protection options considered for St. Michael included the following:

1. Construction of a levee to protect the most vulnerable (north) part of town. The levee would protect 10 residences and access to 16 other homes. The sewage lagoons would still need to be relocated along with construction of a lift station (for the north sewage lagoon) to maintain service to the existing homes.

2. Relocation of the town's sewage lagoons and the affected residences.

Because of the topography around St. Michael, the base of a levee would have to be located where the ground is at elevation 1450, and would be quite expensive relative to the value of the homes, which have a low structure elevation of 1460 or higher. Therefore, the most economical flood protection strategy is incremental relocations. The first increment of protection would be to relocate the North Sewage Lagoon at a lake elevation of 1447.

Feature 6: Gilbert C. Grafton Military Reserve

The most economical flood protection strategy for this feature was found to be incremental relocations and raises of the entrance road. The first action would be relocation of the munitions facility at the current lake level.

Feature 7: Grahams Island State Park

Flood protection options considered for Grahams Island State Park included the following:

1. Relocation of buildings.

2. Relocation / replacement of comfort station and lift station.

3. Relocation / replacement of a picnic area.

4. Road raise on access road from ND Highway 19.

Other options considered included developing an alternate access road to the south of Grahams Island across Ziebach Pass. However, the costs of this option were far greater than raising the existing access from Highway 19, and were therefore not considered further. The first action level of flood protection would be at the current lake level where the access road would be raised.

Feature 8: Rural Features

Relocation is the only protection strategy considered for rural structures. Structures included in the analysis included the following:

1. Houses (on-reservation).

2. Houses (off-reservation).

3. Barns (including larger prefabricated metal buildings as well as timber barns).

4. Sheds (including machine and tractor storage buildings and smaller pre-fabricated structures).

5. Silos (including grain storage bins and silos).

6. Churches.

7. Commercial and Industrial buildings (stores, commercial, and public buildings).

In addition, land damages and costs were considered in this investigation. Relocations would be conducted as needed if the lake continues to rise.

Feature 10*: *Canadian Pacific Railroad

The current low rail elevation is 1450; however, the railroad is currently out of service due to damage that has already occurred due to damage of the railroad embankments by high water. The only available incremental flood protection strategy, apart from abandonment, is repairing and incrementally raising the railroad. Work at the first action level at the current lake level would be a raise of the railroad to a top of rail elevation of 1458.

Feature 11: Burlington Northern Railroad (Along US Highway 2)

The analysis of the Burlington Northern Railroad (along US Highway 2) considered one flood protection strategy (apart from abandonment). At the first action level, that flood protection strategy was the only strategy that was feasible both from an economic and a constructibility standpoint. The strategy involved raising the rail line from a top of rail elevation of 1456 feet msl to an elevation of 1467 feet msl. This would allow for a maximum lake elevation of 1463 with 4 feet of freeboard. Incremental raises of this rail line were not feasible due to the high cost of raising the two bridges and the impacts of repeated closures of this line. The construction initiation lake level for this feature is elevation 1450 feet msl.

Feature 16: US Highway 281 (South of US Highway 2)

The North Dakota Department of Transportation is currently planning to realign US Highway 281 (South of US Highway 2) to provide protection to this feature up to lake level 1463. The realignment will place most of US Highway 281 (South of US Highway 2) outside of the maximum flood extents of the lake. In the areas where the existing ground is below 1465, the highway will be constructed to a minimum elevation of 1465.

Feature 17: US Highway 281 (North of US Highway 2)

The North Dakota Department of Transportation plans to raise US Highway 281 north of US Highway 2 and south of Cando from a minimum road surface elevation of 1454 to a minimum elevation of 1457.4. The roadway embankment will also be widened along the entire length (below 1465) to accommodate potential future raises up to road surface elevation 1465 without requiring fill placement below water. The construction initiation level for this feature is a lake elevation of 1451 feet msl.

Feature 19: ND Highway 1

Included in the study because the road crossed Stump Lake at a minimum elevation of 1410 feet msl. The general protection strategy for this feature consists of a road relocation to the east side of Stump Lake with a minimum road elevation of 1464 feet msl. This work was completed in 2002.

Feature 22: ND Highway 20 (ND Highway 57 to Tokio)

The study of ND Highway 20 (ND Highway 57 to Tokio) considered one incremental flood protection strategy (apart from abandonment) for ND Highway 20 (ND Highway 57 to Tokio). At the first action level, that flood protection strategy would be the only strategy that would be feasible both from an economic and a constructibility standpoint. The strategy would involve raising the road from a minimum road surface elevation of 1445 to a minimum elevation of 1457.5. This constitutes a 5-foot raise for the majority of the roadway being raised and a 13.5-foot raise for the 2,000-foot section with the current road surface at 1445. The construction initiation elevation of the road raise would be at the current lake level.

Feature 23: BIA Highway 1

The study for BIA Highway 1 considered one incremental flood protection strategy (apart from abandonment) for BIA Highway 1. At the first action level, that flood protection strategy was the only strategy that was feasible both from an economic and a constructibility standpoint. The strategy involved raising the road 5 feet to a minimum road surface elevation of 1456.

Feature 24: BIA Highway 6

The BIA started construction of a raise to the low section of Feature 24 in the fall of 2002. The construction involved raising 4,700 feet of BIA Highway 6 from a minimum road surface elevation of 1440 feet msl to a minimum elevation of 1456.9 feet msl. The roadway embankment will also be widened along that length to accommodate potential future raises up to a road surface elevation of 1465 feet msl without requiring fill placement below water. The construction initiation lake level for a road raise at the next action level would be at elevation 1454.

Summary of More Detailed Analysis at First Action Level

The following tables summarize the results of this study for the first action level for the 16 features that were analyzed in detail. Table 5-19 summarizes the economics results. Table 5-20 summarizes the decision critical lake levels for the 16 features analyzed in detail.

Table 5-19: Most Likely Future Without Project – Summary of Economics Analysis Flood Protection Strategies at First Action Level

Feature Number	Feature Name	Flood Protection Strategy Having Largest Net Benefits	Present Worth[1] Total First Costs for First Action Level	Present Worth[1] Damages Prevented	Present Worth[1] Annual Damages Prevented[2]	Stochastic Analysis Average Annual Net Benefits[3]	Stochastic Analysis Benefit-Cost Ratio	Wet Future Scenario Analysis Average Annual Net Benefits[3]	Wet Future Scenario Analysis Benefit-Cost Ratio
1	Churchs Ferry	Relocation of All Structures Below 1468	$ 1,946,000	$ 1,479,000	--	$ (6,100)	0.76	$ (22,400)	0.76
2	City of Devils Lake	One Incremental Levee Raise	$ 6,327,000	$223,729,000	--	$ 1,294,000	5.74	$ 10,392,400	29.46
3	Fort Totten	One Incremental Relocation	$ 4,753,000	$ 3,638,000	--	$ (19,900)	0.77	$ (60,200)	0.77
4	City of Minnewaukan	One Incremental Levee Raise	$ 11,298,000	$ 10,493,000	--	$ (23,600)	0.85	$ (62,000)	0.89
5	St. Michael	One Incremental Relocation	$ 582,000	$ 409,000	--	$ (10,500)	0.70	$ (10,500)	0.70
6	Gilbert C. Grafton Military Reservation	Relocation of All Structures	$ 1,514,000	$ 970,000	--	$ (33,000)	0.64	$ (33,100)	0.64
7	Grahams Island State Park	One Incremental Road Raise	$ 5,668,000	$ 531,000	$ 516,000	$ (67,500)	0.80	$ 173,000	1.50
8.1	Devils Lake Rural Areas	Five Incremental Relocations	$ 23,511,000	$ 17,055,000	--	$ (218,500)	0.72	$ (359,500)	0.72
8.2	Stump Lake Rural Areas	Eight Incremental Relocations	$ 2,982,000	$ 1,960,000	--	$ (22,900)	0.66	$ (53,100)	0.66
10	Canadian Pacific Railroad	One Incremental Rail Raise	$ 23,234,000	--	$ 533,000	$ (654,500)	0.54	$ (1,193,600)	0.16
11	Burlington Northern Railroad (along US	Raise Rail to Maximum Level	$ 48,583,000	--	$ 4,333,000	$ (62,600)	0.87	$ 1,060,300	1.48
16	US Highway 281 (South of US Highway 2)	Relocation of Road	$ 46,031,000	--	$ 3,861,000	$ 315,600	1.11	$ 2,733,000	1.98
17	US Highway 281 (North of US Highway 2)	One Incremental Road Raise	$ 9,953,000	--	$ 1,403,000	$ (15,300)	0.88	$ (207,000)	0.57
19	ND Highway 1	- NA -	--	--	--	- NA -	- NA -	- NA -	- NA -
22	ND Highway 20 (between ND Highway 57 and Tokio)	One Incremental Road Raise	$ 17,858,000	--	$ 611,000	$ (532,300)	0.51	$ (826,000)	0.24
23	BIA Highway 1	One Incremental Road Raise	$ 3,004,000	--	$ 1,012,000	$ 161,900	2.27	$ 125,300	1.73
24	BIA Highway 6	- NA -	--	--	--	- NA -	- NA -	- NA -	- NA -

Notes
1 Total first costs are actual flood protection costs, in present value. Values for damages and annual damages are also listed in present value
2 Annual damages prevented during years that the feature would have been damaged by the lake. The benefit of avoiding restoration damages (damages registered when a previously inundated road or railroad is repaired and made ready for use again) is not represented
3 The net benefits listed were averaged over 10,000 traces. The averages were then annualized over a 50-year period.

Table 5-20: Most Likely Future Without Project – Lake Levels for Flood Protection Action, Flood Protection Strategies at First Action Level

			Decision-Critical Lake Elevations[2]												
Feature Number	Feature Name	Protection Strategy Having Largest	Costs for First Action Level	Current	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	Notes
1	Churchs Ferry	Relocation of All Structures Below 1468	$ 1,946,000					PC,LD	LS						
2	City of Devils Lake	One Incremental Levee Raise	$ 6,327,000	PI	CI				PC			LD		LS	
3	Fort Totten	One Incremental Relocation	$ 4,753,000		LD	LS									
4	City of Minnewaukan	One Incremental Levee Raise	$11,298,000		PI			CI, LD	LS	PC					Temporary Protection of Low Homes
5	St. Michael	One Incremental Relocation	$ 582,000	PI, CI, PC, LD				LS							
6	Gilbert C. Grafton Military Reservation	Relocation of All Structures	$ 1,514,000	PI, CI, PC, LD, LS											Protected by Roads Acting as Dams
7	Grahams Island State Park	One Incremental Road Raise	$ 5,668,000	PI, CI, PC, LD				LS							
8.1	Devils Lake Rural Areas	Five Incremental Relocations	$23,511,000												Broad Range of Elevations
8.2	Stump Lake Rural Areas	Eight Incremental Relocations	$ 2,982,000												Broad Range of Elevations
10	Canadian Pacific Railroad	One Incremental Rail Raise	$23,234,000	PI, CI, PC, LD			LS								
11	Burlington Northern Railroad (along US Highway 2)	Raise Rail to Maximum Level	$48,583,000				PI		CI, LD				LS		
16	US Highway 281 (South of US Highway 2)	Relocation of Road	$46,031,000	PI, CI, LD			LS								
17	US Highway 281 (North of US Highway 2)	One Incremental Road Raise	$ 9,953,000		PI			CI, LD			LS				
19	ND Highway 1	- NA -	--												LS=1465, Has been relocated
22	ND Highway 20 (between ND Highway 57 and Tokio)	One Incremental Road Raise	$17,858,000	PI, CI, PC, LD, LS											Protected by Roads Acting as Dams LS=1445
23	BIA Highway 1	One Incremental Road Raise	$ 3,004,000	PI	CI, LD			LS							
24	BIA Highway 6	- NA -	--												Being raised to LS=1457

LS = Low Structure, LD = Lake Damage, PC = Project Completion, CI = Construction Initiation, PI = Project Initiation.

Notes
1 Total first costs are actual flood protection costs, in present value. Values for damages and annual damages are also listed in present value.
2 Decision-critical elevations are rounded to the nearest foot.

Table 5-21: Most Likely Future Without Project – Economics Summary
Flood Protection Strategies up to Lake Level 1463

			Present Worth[1]			Stochastic Analysis		Wet Future Scenario		
Feature Number	Feature Name	Flood Protection Strategy Having Largest Net Benefits	Total First Costs	Total Damages Prevented	Annual Damages Prevented[2]	Average Annual Net Benefits[3]	Benefit-Cost Ratio	Average Annual Net Benefits[3]	Benefit-Cost Ratio	Lake Level of First Damages
1	Churchs Ferry	Relocation of All Structures	$ 1,946,000	$ 1,479,000	--	$ (6,100)	0.76	$ (22,400)	0.76	1451
2	City of Devils Lake	Incremental Levee Raises	$ 78,174,000	$ 305,380,000	--	$ 365,200	1.30	$ 6,972,700	2.84	1454.5
3	Fort Totten	Incremental Relocations	$ 5,367,000	$ 4,086,000	--	$ (20,500)	0.76	$ (65,600)	0.76	1448
4	City of Minnewaukan	Incremental Levee Raises	$ 17,605,000	$ 25,042,000	--	$ (25,300)	0.88	$ 149,700	1.17	1452
5	St. Michael	Incremental Relocations	$ 1,720,000	$ 1,224,000	--	$ (11,700)	0.71	$ (21,200)	0.71	Current[4]
6	Gilbert C. Grafton Military Reservation	Relocation of Munitions Facility	$ 1,514,000	$ 970,000	--	$ (33,000)	0.64	$ (33,100)	0.64	Current
7	Grahams Island State Park	Incremental Road Raises and Structure	$ 23,764,000	$ 2,718,000	$ 516,000	$ (66,400)	0.86	$ (414,400)	0.59	Current
8.1	Devils Lake Rural Areas	Incremental Relocations	$ 79,764,000	$ 58,670,000	--	$ (273,700)	0.72	$ (831,300)	0.73	Current
8.2	Stump Lake Rural Areas	Incremental Relocations	$ 5,457,000	$ 3,547,000	--	$ (28,700)	0.65	$ (87,700)	0.65	1413
9	Red River Valley and Western Railroad	N/A	--	--	--	--	--	--	--	N/A
10	Canadian Pacific Railroad	Incremental Rail Raises	$ 67,260,000	--	$ 533,000	$ (895,900)	0.48	$ (2,646,700)	0.17	Current
11	Burlington Northern Railroad (along US	Raise Rail to Maximum Level	$ 48,583,000	--	$ 4,333,000	$ (62,600)	0.87	$ 1,060,300	1.48	1452
12	Burlington Northern Railroad (Churchs Ferry to Cando)	Incremental Rail Raises	$ 69,394,000	--	$ 509,000	$ (179,100)	0.19	$ (1,595,500)	0.20	1451
13	US Highway 2	Incremental Road Raises	$ 152,738,000	--	$ 11,863,000	$ 88,200	1.15	$ 2,298,800	1.47	1452
14	ND Highway 57 (between ND Highway 20 and BIA Highway 1)	Incremental Road Raises	$ 14,274,000	--	$ 13,104,000	$ 646,100	11.57	$ 7,251,000	16.25	1452
15	ND Highway 57 (between BIA Highway 1 and US Highway 281)	Incremental Road Raises	$ 42,667,000	--	$ 9,488,000	$ 353,400	3.05	$ 4,250,500	4.05	1452
16	US Highway 281 (South of US Highway 2)	Relocation of Road	$ 46,031,000	--	$ 3,861,000	$ 315,600	1.11	$ 2,733,000	1.98	Current
17	US Highway 281 (North of US Highway 2)	Incremental Road Raises	$ 38,459,000	--	$ 1,403,000	$ (35,200)	0.85	$ (198,300)	0.86	1451
18	ND Highway 19	Incremental Road Raises	$ 101,252,000	--	$ 1,322,000	$ (289,000)	0.29	$ (2,379,100)	0.28	1452
19	ND Highway 1	- NA -	--	--	--	--	--	--	--	1462
20	ND Highway 20 (North of City of Devils Lake)	Incremental Road Raises	$ 33,382,000	--	$ 3,375,000	$ (26,200)	0.66	$ (29,100)	0.97	1457
21	ND Highway 20 (City of Devils Lake Dike to ND Highway 57)	Incremental Road Raises	$ 24,859,000	--	$ 13,104,000	$ 606,900	6.71	$ 6,915,500	9.35	1452
22	ND Highway 20 (between ND Highway 57 and Tokio)	Incremental Road Raises	$ 37,987,000	--	$ 611,000	$ (592,300)	0.50	$ (1,210,800)	0.34	Current
23	BIA Highway 1	Incremental Road Raises	$ 11,382,000	--	$ 1,012,000	$ 188,400	2.08	$ 469,100	1.97	1448
24	BIA Highway 6[5]	Incremental Road Raises	$ 8,442,000	--	$ 13,873,000	$ 740,900	35.46	$ 8,016,700	52.59	1453.9
		CUMULATIVE TOTAL	**$ 912,021,000**	**$ 403,116,000**	**$ 78,907,000**	**$ 759,000**	**1.07**	**$ 30,582,100**	**1.86**	

Notes

1. Total first costs are actual flood protection costs, in present value. Values for damages and annual damages are also listed in present value.
2. Annual damages prevented during years that the feature would have been damaged by the lake. The benefit of avoiding restoration damages (damages registered when a previously inundated road or railroad is repaired and made ready for use again) is not represented in this table.
3. The net benefits listed were averaged over 10,000 traces. The averages were then annualized over a 50-year period.
4. Currently protected by temporary dikes and roads that are acting as dams.
5. Currently protected by tempoary dikes and roads that are acting as dams, and is being raised to a minimum elevation of 1456.9.

Summary of Analysis for All Features and All Action Levels

Results of the Most Likely Future Condition for all features and for lake levels up to 1463 feet are shown in Table 5-21. For the 16 features for which more detailed analysis was performed for the first action level, higher action levels were analyzed by combining the new work at the first action level with the previous work. For the eight features that were not examined in the more detailed analysis, the table presents results of the previous analysis. Figure 5-47 is a graph depicting the cumulative infrastructure costs of the 24 features by elevation.

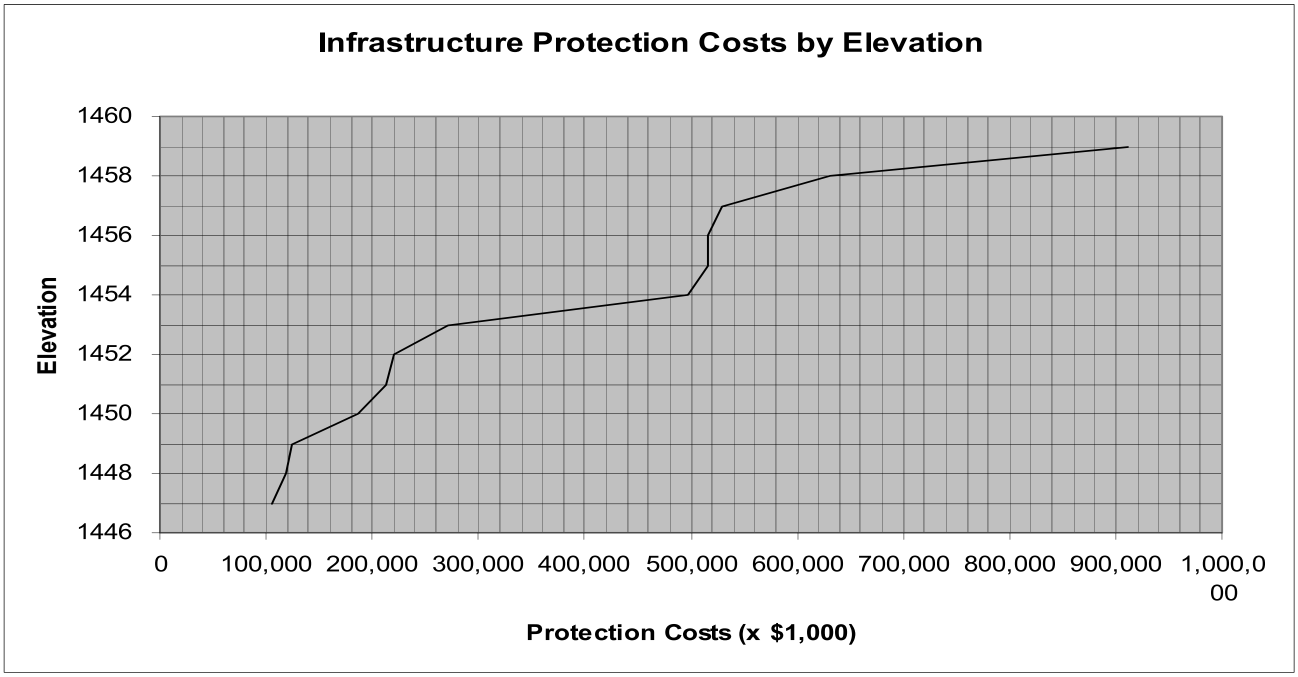


Figure 5-47: Infrastructure Protection Costs by Elevation

Outlet Plan – Pelican Lake 300-cfs Outlet (Preferred Alternative)

For the Pelican Lake 300-cfs outlet plan, three different design studies were performed by Barr Engineering to better define the main components of this feature related to moving water from Pelican Lake to the Sheyenne River. The studies were a Feature Design Report that evaluated and selected the main components for the outlet, a Feature Design Report that evaluated and identified features of the Dry Lake Diversion component of the outlet, and a Design Development Report that performed detailed design of the main portion of the outlet.

Additional components of the outlet were identified by other studies performed for the outlet. The most important of these studies were the biota transfer study performed by the Corps of Engineers Engineering Research and Development Center, and the monitoring and mitigation proposal prepared by Peterson Consultants.

Components

Beginning in the upper basin, the components of the Pelican Lake 300-cfs outlet with estimated first costs in parentheses are described as follows:

A. ***Dry Lake Diversion***

This component would be a modification of the existing Dry Lake - Channel A project to restore a portion of the historic flow of fresh water from Dry Lake to Pelican Lake via a chain of lakes and Big Coulee. The lakes included in the chain include Mikes Lake, Chain Lake, Lake Alice, and Lake Irvine. Lake Alice is the home of the Lake Alice Natural Wildlife Refuge. The Dry Lake Diversion is shown on Figure 5-48. The location of the area shown on this map relative to the rest of Devils Lake and the Pelican Lake Outlet is indicated on Figure 5-4.

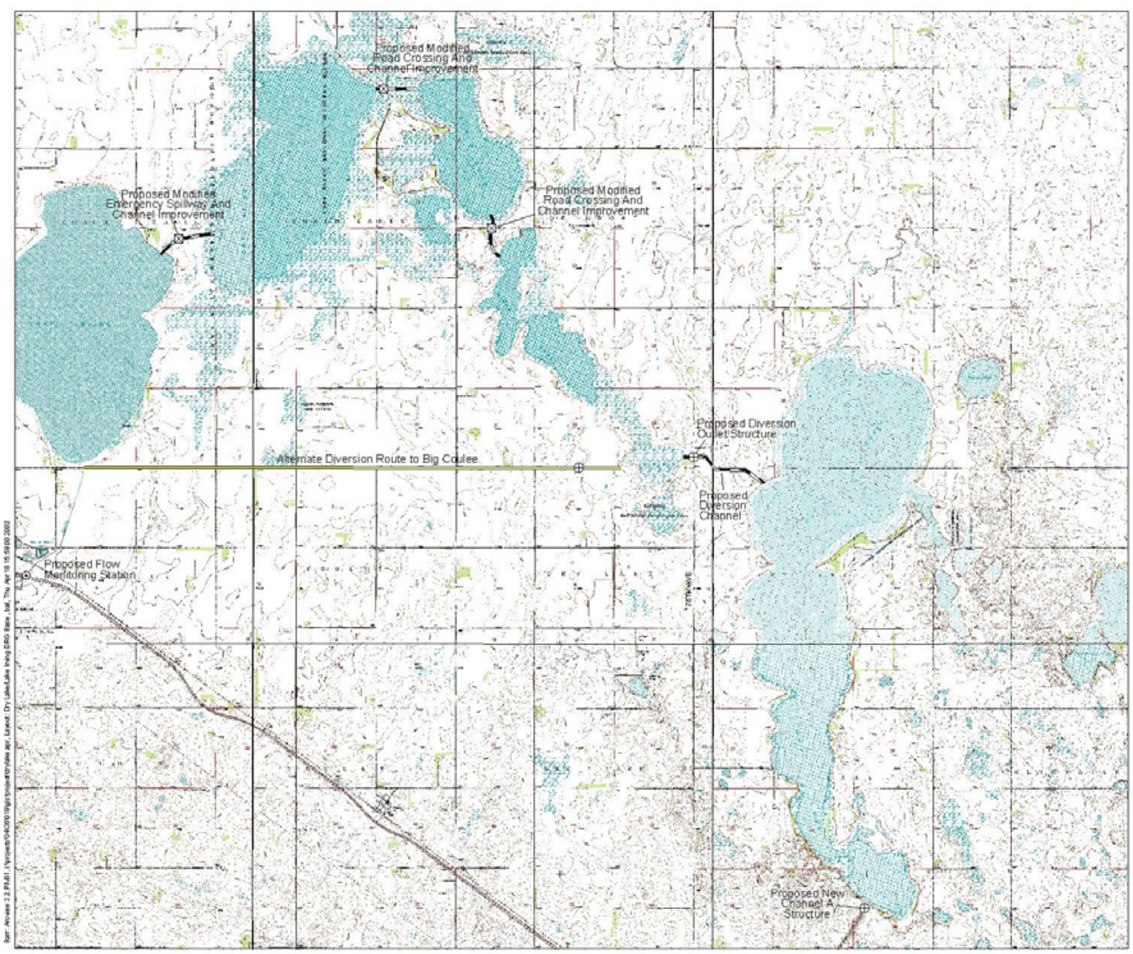


Figure 5-48: Dry Lake Diversion

The introduction of additional water with lower sulfate concentrations to Pelican Lake would allow the operation of the proposed Devils Lake Outlet to be more effective and feasible in lowering lake levels. For a discussion of the need for this component, please refer to the “Sensitivity Analysis of the Incremental Analysis of the Dry Lake Diversion” in the section on “Evaluation of Alternatives.” This component would consist of the following features:

1. Construct a channel between Dry Lake and Mikes Lake. A large culvert would be required to convey the flow from Dry Lake to Mikes Lake under 75th Avenue Northeast. A stop log control structure would be built at the upstream end of the culvert.

2. Construct an embankment with gated culverts across Channel A downstream of the existing Channel A control structure.

3. Perform channel improvements, roadway crossing improvements, and control structure improvements in the Chain of Lakes to provide more flow capacity.

4. Obtain flowage easements around Dry Lake to elevation 1458 and around Lake Alice, Chain Lake, and Mikes Lake to elevation 1446.

5. Establish a discharge gaging station on Big Coulee to provide data for project operation.

6. Conduct cultural resources surveys in flowage easement areas around Dry Lake and Chain of Lakes.

The above diversion plan minimizes the amount of construction required and is the lowest cost alternative, but would require a statement of compatibility with the Lake Alice National Wildlife Refuge. As an alternate to this plan, a channel directly from Channel A to Big Coulee was conceptually developed. This plan was estimated to cost $13,121,000 and therefore was not selected. However, if the selected plan is determined to be incompatible with the Lake Alice National Wildlife Refuge, then the alternate diversion channel could be implemented instead for a moderate increase in the total project cost.

B. ***Open Channel***

The open channel would be approximately 7.8 miles long and would convey water from Pelican Lake to the pump station on the north side of Minnewaukan. Most of the alignment is low enough that the length of excavated channel would only be about 2.6 miles. The excavated portion of the channel would have a bottom width of 25 feet and 3 to 1 side slopes. Concrete box culverts would be required where the open channel crosses Highway 281 and Schneider’s Crossing (gravel township road north of the pump station). The Open channel and all of the main portions of the Outlet are shown on Figure 5-49.

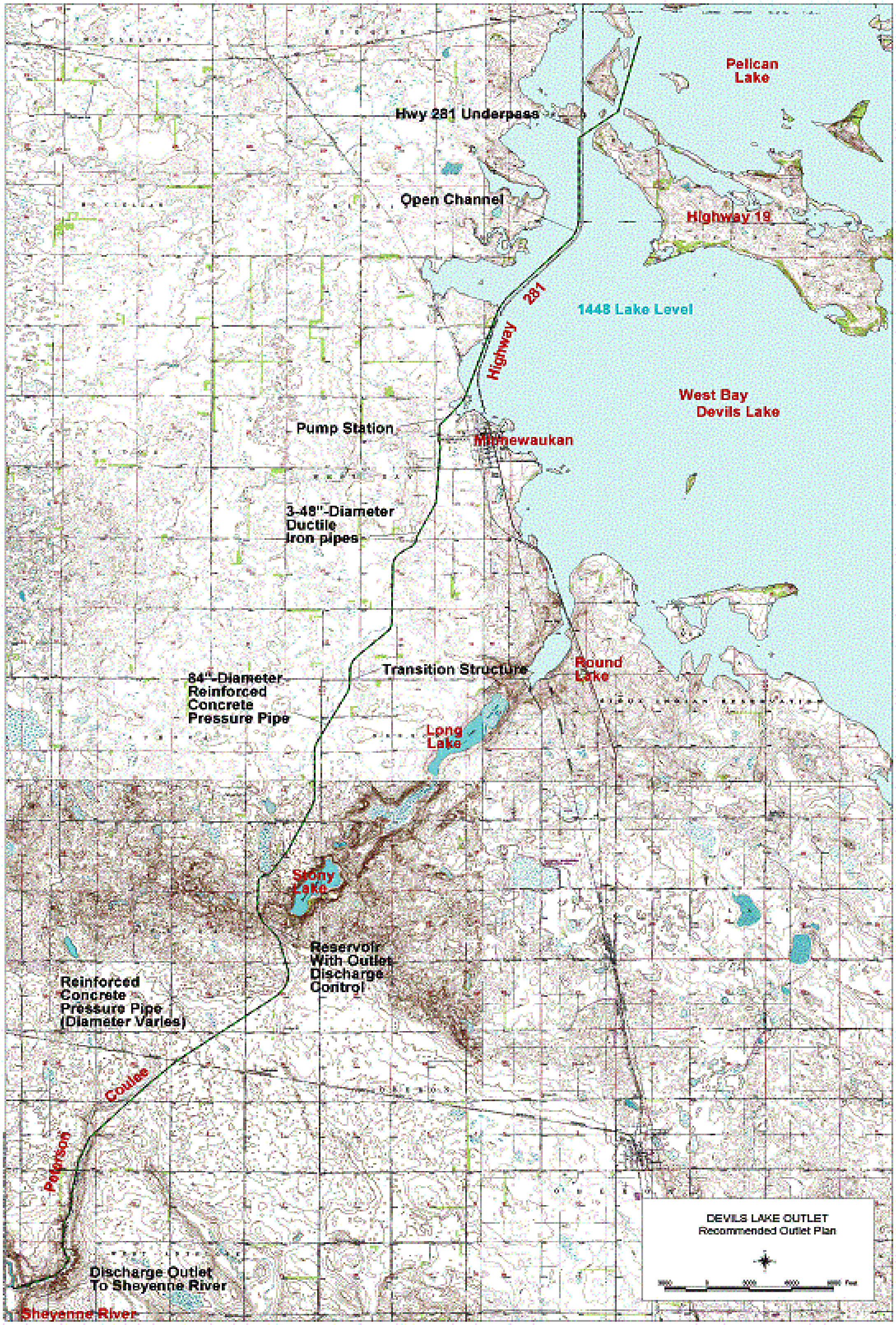


Figure 5-49: Proposed Devils Lake Outlet

C. ***Highway 281 Flow Separation Embankment***

A separation embankment would be constructed on Highway 281 between Minnewaukan and Highway 19, if the Highway Department relocates this stretch of road and does not raise it. The embankment would have a top elevation of 1455, sized to fit on top of the existing road embankment while still providing erosion protection and enough top width to construct and maintain it. Highway 19 would also be used for flow separation, from Highway 218 to the west edge of Grand Harbor Township. Highway 19 is already at elevation 1455. In addition to the embankment, approximately 21 existing culverts under Highways 281 and 19 would be plugged to provide more flow separation. When the lake returns to lower levels in the future, the culverts could readily be put back in service to restore drainage through the road embankment. Costs for this component are included with the Inlet Channel in the Cost Summary table.

D. ***Pump Station***

A pump station located on the northwest side of Minnewaukan would receive water from the open channel and convey water to the control reservoir located south-southwest out of the pump station through the pressure pipeline segments. The pump station would include three 100-cfs pumps. The electric motors for the pumps would be almost 4,000 horsepower, sized to pump against the maximum design head of 240 feet. The substructure for the pump station is designed as a conventional reinforced concrete wet well-type structure, designed to operate for lake elevations between 1441.5 and 1463. The bottom of the wet well would be at elevation 1426 and the top of the concrete substructure would be at elevation 1467, higher than any potential lake elevation. Because of a very weak layer of soil near the base of the structure, the substructure would be founded on short H-piles driven into the pier shale foundation. A combined trash rack and fish screen is incorporated into the pump station intake design. The screen would be a fixed-type configuration, cleaned by a rake system. A metal superstructure would be provided to protect the motors, valves, and operating equipment. Roof hatches would provide maintenance access into the pump station for the removal and installation of motors and valves.

E. ***Ductile Iron Pressure Pipeline***

From the pump station, flow from each pump would be conveyed in three 48-inch-diameter buried ductile iron pipes (DIPs). Like all pipeline on this project, they would be buried to frost depth. Compressed air surge tanks would be located at the beginning of these pipes to protect the pump station in case of sudden shutdown. The ductile iron pipes would run approximately 2.3 miles to the south-southwest where they would connect to a concrete transition structure.

F. ***Concrete Pressure Pipeline***

A single 84-inch buried reinforced concrete pressure pipe (RCPP) would extend approximately 5.5 miles south-southwest, conveying water from the concrete transition structure at the end of the DIP to a sand filtration system at the watershed divide between the Devils Lake basin and the Sheyenne River basin.

G. ***Sand Filtration System***

The sand filtration system was added late in the analyses to address biota and invasive species transfer issues. It is intended to filter much of the organic material from the water transferred through the outlet and would be located between the pressure pipeline and the control reservoir. Due to its late addition to the design, the filtration system has only been conceptually designed at this time. It appears that a gravity-type, deep-bed rapid sand filtration system would best meet the requirements of this application. The Sand Filtration system is not shown on Figure 5-49, but it would be collocated with the control reservoir. It would consist of the following features:

1. ***Filter Tanks:*** The filters would be open-air tanks constructed of concrete using common wall construction. The conceptual design assumes a layout of two filter trains consisting of seven filters in each train, each approximately 1,000 square feet in area.

2. ***Media:*** For this conceptual design, it was assumed that a dual-media filter bed would provide the most efficient filtration. The dual-media filter bed would consist of a layer of coarser anthracite coal on top of a layer of finer silica sand. This type of system encourages better penetration of solids and thus better bed utilization. Additional analyses would be required prior to the final media selection.

3. ***Underdrain System:*** An underdrain system would be placed below the media to collect the filtrate. It is assumed that the underdrain system would not be placed in a gravel bed, but rather constructed as part of the floor system to allow for combined air-water backwashing of the filtration media. The filtered effluent would be conveyed via a common effluent manifold to a clear well.

4. ***Clear Well:*** A clear well would be required to provide an adequate supply of clean water to backwash the filters. The treated filter effluent would be used to backwash the filters and an overflow weir would be used to provide submergence for the backwash pumps. The effluent from the clear well would discharge to the control reservoir through an 84-inch RCPP. It is assumed that the clear well would be constructed of cast-in-place concrete and would include a building for housing the backwash pumps.

5. ***Backwashing System:*** It was assumed that the filtration system would use combined air-water backwash. The backwashing system would obtain supply water from the clear well and a blower would supply the required airflow. Two 15,000-gpm vertical turbine pumps would provide the backwash water from the clear well. Backwash events would

be controlled by water levels in the filter cells. The backwash water would be treated on site.

6. ***Backwash Water Treatment:*** The backwash water would be routed to one of two 70-foot-diameter clarifiers. The clarifiers would have center pier rake assembly for sludge collection. The clarifier would provide solids removal from the backwash water through gravity settling. The clarified effluent would be routed back to the sand filtration system influent by one of two clarifier effluent booster pumps for treatment prior to discharge to the control reservoir. Sludge that settles in the clarifier would be removed from the bottom of the clarifiers as needed by sludge pumps and discharged to sludge drying beds for dewatering.

7. ***Sludge Drying Beds:*** Sludge drying beds would be constructed on nearby available land for dewatering of the backwash sludge. Based on the estimated 16,300 pounds per day of solids, it is anticipated that the sludge drying bed area required would be 395,000 square feet per year. Assuming the beds are cleaned once every 2 years, the total area required would be 790,000 square feet.

8. ***Controls:*** The system controls would be housed in a structure located between the filter trains. The structure would also house the blower required for the backwash system.

H. ***Control Reservoir***

A control reservoir is located at the high point along the outlet route, providing a point where flow rate to the Sheyenne River is controlled. The large pumps at the pump station would be alternately started and stopped to obtain a desired average flow rate. The reservoir has been sized to attenuate the flow surges produced by the alternately running pumps into a relatively smooth flow output. The sand filtration system located immediately upstream of the control reservoir would not be expected to appreciably attenuate the flows. To minimize the number of starts required for the very large pumps and motors, the reservoir provides water storage and flow control in three separate cells. The reservoir area would be contained by earthen side berms that make the total reservoir land area approximately 84 acres.

I. ***Concrete Gravity Pipeline***

Approximately 6.5 miles of buried RCPP would extend from the reservoir, conveying water to the Sheyenne River. The route generally follows the alignment of Peterson Coulee. The pipe would vary in diameter from 84 inches in diameter on the flat upper reaches of the alignment to 66 inches in diameter in the steeper reaches along the bottom of Peterson Coulee. At the end of this pipe, flow would discharge into a 90-foot-long steel plate arch structure that would provide for expansion and slowing of the water as it enters the river.

J. ***Sheyenne River Gaging Stations***

Gaging stations upstream and downstream of the discharge point on the Sheyenne River would provide the monitoring needed for project operation. Costs for this component are included with the Pump Station in the Cost Summary table.

K. *Modification of Low-Head Dams on the Sheyenne River*

There are 14 low-head, weir type dams on the Sheyenne River between the insertion point of the outlet and the Red River. The low-head dams should not pose a dam safety threat in the sense of dam failure, sending a surge of water downstream, but at times they may be dangerous for persons or livestock with respect to drowning. The drowning hazard caused by the "roller effect" on the downstream side of most of the low-head dams is already a problem during higher flows and would likely be worse due to the outlet because of the longer duration of higher flows. To mitigate safety concerns created by the larger “roller,” 10 dams would be modified by placing rock fill on their downstream side at a slope of four on one. These 10 dams would be all of the dams between the insertion point and the City of Lisbon, North Dakota, that do not currently have sloping faces on their downstream side. There are three dams in the lower Sheyenne River near West Fargo, North Dakota, that would not be included because they are far enough downstream from the outlet that the flow increase would be minor and higher flows are mitigated by the presence of the Horace to West Fargo Diversion. In addition to the rock fill in the river below the dam, it is assumed that some riprap erosion protection would be added to the abutments on each side of the dam to control erosion created by the additional flows from the outlet.

L. *Flowage Easements on the Sheyenne River*

The outlet would be operated so that the discharge from the outlet would create total flows in the Sheyenne River of no more than 600 cfs. This flow rate would result in out-of-bank flooding on approximately 3,500 acres. Flowage easements would need to be purchased on lands that were flooded at 600 cfs and are not part of mitigation features. This would result in a requirement to purchase flowage easements on 1,880 acres.

M. *Environmental Mitigation on the Sheyenne River*

1. ***Terrestrial Mitigation:*** Hydrologic modeling of the Pelican Lake 300-cfs constrained outlet suggests that increased flooding, erosion, groundwater levels, and/or soil salinization related to the discharge would affect approximately 6,000 acres. Although the river would not be expected to flood regularly during project operation due to constraints on flow imposed by channel capacity, it would frequently overflow into adjacent low meander cutoffs and oxbow lakes, and groundwater levels would increase. Because the upper Sheyenne is less deeply entrenched than the portion of the river below Baldhill Dam and is more susceptible to flooding and elevated groundwater, three-quarters of the predicted impact area would lie above Lake Ashtabula. Mitigation for groundwater effects to terrestrial resources would include the fee title acquisition and

management of approximately 6,000 acres of riparian lands along the Sheyenne River. Management measures would include plantings, fencing, transplanting, food plots, wildlife structures, etc.

2. ***Aquatic Habitat Preservation Through the Creation of Cutoffs Across Meanders:*** The goal of this feature is to maintain enough diversity of habitat to allow post-outlet operation to reestablish pre-outlet operation communities. It is recognized that the diverse habitat types in the Sheyenne River are key to the existence of diverse species in the river. Of particular concern is the potential loss of riffle-pool habitat. Therefore, this feature will provide for the continued existence of this critical habitat type.

Nine sites have been identified on the upper Sheyenne River to accomplish this. The sites were selected in areas already chosen for terrestrial mitigation where a high length of bypass to length of natural channel could be obtained. The sites avoid the following: existing structures or other developed areas, including roads; the outer edge of existing meanders, to reduce the likelihood that future river migration would merge the natural and artificial channels; and wooded areas.

A conceptual design was developed to determine features that could be used to implement the mitigation plan. Exact features would need to be developed for each specific site in a later design phase. The features are:

a. An embankment control structure across the river at the head of the meander. It would be approximately 7 or 8 feet high with approximately two 48-inch-diameter concrete pipes through its base.

b. An earthen bypass channel extending from upstream of the Sheyenne River control structure to the downstream end of the meander.

c. An embankment control structure at the head of the bypass channel with approximately six 48-inch-diameter concrete pipes through its base. This embankment would extend at least to the height of the floodplain. The invert of these pipes would be located at the same elevation as the top of the two pipes in the Sheyenne River control structure.

d. A riprap and/or sheet pile erosion control structure at the downstream end of the bypass channel.

The intent of this feature is to maintain a flow regime in the existing meander similar to what currently exists. These features will permit low flows to pass through the Sheyenne River control structure and continue down the existing Sheyenne River channel. For intermediate flows between approximately 100 and 600 cfs that are expected to exist with much greater frequency under outlet operation, a substantial portion of the flow would pass down the bypass channel. For flows above 600 cfs, which would be naturally occurring flood flows, the Sheyenne River control structure would be overtopped and a substantial amount of flow would go in the existing river channel. The flow in the natural channel would increase as the river flow increases above 600 cfs since the bypass channel embankment would prevent flow in the bypass channel except for what passes through the pipes, as long as the river flow is below bank-full conditions.

3. ***Erosion Protection:*** The increased flow resulting from the proposed pumping alternative would cause increased river stages and duration of inundation. This change may result in an increased rate of erosion in certain sections of the river and could have a detrimental effect on some forms of riparian vegetation. In addition to weakening of the banks due to vegetative loss, increased shear stresses and velocities along the bed and banks may increase the rate of bank erosion. The Sheyenne River is currently in a state of quasi-equilibrium or stability. The significant changes in the timing and magnitude of flow caused by the proposed 300-cfs diversion would likely force the Sheyenne River to an unstable state. In addition to erosion, this operational change could result in an increase in sediment transport and deposition.

Erosion protection measures, for sites identified as high potential, consisting of a combination of riprap, bioengineering, and other structural measures, are proposed on 23 sites located downstream of the insertion point and downstream of Baldhill Dam. The purpose of the erosion protection would be to minimize the turbidity and sedimentation that would occur at any particular location, which would reduce impacts to aquatic resources.

N. ***Environmental Monitoring in Devils Lake and the Red River Basin***

Mitigative measures are included to help avoid/minimize impacts through project design. Where unavoidable impacts occur, mitigation is proposed to facilitate the recovery of the system after the project ceases operation. Monitoring is proposed to further quantify unknown effects and determine if modifications to the mitigation measures are required. The following monitoring is proposed:

- Collection of data for dissolved oxygen, conductivity, temperature, salinity, turbidity, chloride, and total dissolved solids at 15 locations in the outlet channel, the Sheyenne River, and the Red River of the North.
- Yearly population surveys of known rare plant sites in the area of potential impact.
- Establishment of approximately 30 sites distributed proportionally in each of the general vegetative communities in the area of potential effect and collection of data yearly during the period of operation to track changes in vegetative community composition.
- Collection of fish in three locations in the Sheyenne River and testing for mercury levels.
- Sampling of soil chemistry along 16 transects in each of 6 soil associations in the area of potential impact.
- Sampling of groundwater chemistry at four locations in the area of potential impact.

- Determination and tracking of soil salinity levels along 20 transects in cropped and hayed areas highly susceptible to adverse salinization impacts.
- Collection of aquatic habitat and community data at 18 locations along the Sheyenne River.
- Monthly sampling during the pumping season for potentially invasive biota in the Pelican Lake outlet channel and the Red River basin.
- Yearly surveys of cultural resource sites in the area of potential impact, using canoe and foot-based inventories in alternating years.
- Yearly evaluation of Valley City Fish Hatchery infrastructure.

The monitoring protocol would be modified as necessary based on the results of the previous monitoring and evaluation. Monitoring would be used to modify the mitigation features as necessary.

O. ***Cultural Mitigation on the Sheyenne River***

Based on the results of a 2000-2001 water-based cutbank reconnaissance survey, there are 54 cultural resources sites visibly eroding from the banks of the Sheyenne River between the mouth of Peterson Coulee downstream to the Red River of the North. A Phase I survey to determine the horizontal limits of each of these sites and Phase II testing to determine each site's physical integrity, vertical extent, and data potential would be conducted to evaluate their eligibility to the National Register of Historic Places. Mitigation at those sites that are determined to be eligible for the National Register would consist of bank protection and/or data recovery.

As cutbank monitoring for eroding cultural resources sites would continue over the operational life of the Pelican Lake outlet, any additional cultural resources sites exposed along the Sheyenne River would be similarly surveyed and evaluated, with bank protection being the main form of mitigation for those sites determined eligible for the National Register. The cost for this additional mitigation is not, however, included in the dollar amount above.

Operation Plan

Operation of Pelican Lake Outlet

Operation of the Pelican Lake outlet would be limited to a 7-month period (May 1 through November 30). Operation would also be constrained by conditions in the receiving waters of the Sheyenne River. Specifically, pumping operations would be constrained at the insertion point to limit flows in the Sheyenne River to no greater than 600 cfs total flow and to limit sulfate concentrations in the Sheyenne River to no more than 300 mg/l. Outlet operation would be curtailed or halted if the flow magnitude or water quality criteria were exceeded by blended waters in the Sheyenne River below the point of insertion.

Operational Considerations

The Corps of Engineers is responsible for the coordination and preparation of an Operation Maintenance manual for the project, which is to ensure that project benefits are achieved and environmental requirements are met following construction of the project. As the expected non-Federal local sponsor for an outlet project, the State of North Dakota would be responsible for operation and maintenance of the project. A Devils Lake Outlet Management Advisory Committee has already been established by the North Dakota State Legislature. The Devils Lake outlet management advisory committee consists of the state engineer or the state engineer's designee, one member appointed by the Red River joint resource board, one member appointed by the Devils Lake Joint Water Resource Board, one county commissioner from both Ramsey County and Benson County, a representative of the Spirit Lake Nation, and three members representing the interests of downstream impacts, as appointed by the governor.

Guidance provided in the State legislation indicates that the committee is to develop an annual operating plan for the operation of the Devils Lake outlet. This plan must specify the lake elevation at which pumping will take place. In developing the annual operating plan, the committee is to consider spring runoff forecasts, weather forecasts, summer flooding potential, downstream impacts including water quality and streambank erosion, flooding, and any other factors the committee determines should be considered.

Since the framework for an operating plan is defined as part of the project description, there will be limited latitude to refinements of the actual operation, without affecting the stage effectiveness of the outlet and downstream impacts. The operating plan for the outlet is intended to utilize the maximum discharge capacity of 300 cfs, which would operate for 7 months, from the beginning of May through the end of November. The flows would be constrained so that the total combined discharge with the Sheyenne River would not exceed 600 cfs and the sulfate levels would not exceed 300 mg/l, both at the insertion point. Modeling for project impacts assumes this plan would be implemented whenever the Devils Lake stages exceed elevation 1443.0. Variations from this plan would require evaluation prior to implementation to assure that reduction of stage effectiveness or increase of any downstream impacts would not be significant. Also, Federal agencies, such as the Corps of Engineers, U.S. Fish and Wildlife Service, and U.S. Geological Survey, as well as the State of Minnesota and Canada, need to be consulted on changes in the operation of the project.

Although the Corps of Engineers would assume responsibility for establishment of instrumentation and operational equipment to assure that the discharges do not exceed the specified constraints, the involvement of this management advisory committee would be essential. Besides the issues of outlet operation, this committee, with consultation from the Federal agencies, would also be instrumental in determining specific locations and details of the monitoring program. The actual collection and evaluation of the data would be a shared responsibility of the Federal government and the non-Federal sponsor.

Monitoring Program System

The following network is planned for operational and compliance monitoring of the operational constraints:

A. ***Pump Station:*** The specific conductance (SC) of the water in the pump station wet well would be monitored continuously during system operation as an indicator of TDS. In addition, water samples would be collected weekly when the system is in operation and analyzed for TDS to verify and adjust the relationship between SC and TDS that is used for system operation. Flow meters would also be installed in the pump discharge pipes, but they would not likely be equipped with continuous monitoring-recording equipment. The primary purpose of these flow meters would be to provide pump operational information.

B. ***Control Reservoir:*** Discharge would be monitored continuously at the outlet of the control reservoir when the system is in operation.

C. ***Sheyenne River Downstream of Peterson Coulee:*** Discharge and SC would be monitored continuously at a new gage to be established on the Sheyenne River downstream of Peterson Coulee and the outlet discharge point.

D. ***Sheyenne River Upstream of Peterson Coulee:*** Discharge and SC would be monitored continuously when the system is in operation at a new gage to be established on the Sheyenne River upstream of Peterson Coulee and the outlet discharge point. The continuous monitoring data would most likely be collected and made available on a real-time basis by the USGS. The pump station control system would electronically and automatically access this data and adjust the system discharge to remain in compliance. In addition, system operating staff would review the monitoring network data and verify proper operation daily for five days per week.

Flow and SC monitoring would be performed using normal USGS methods. SC and water temperature would be measured using standard USGS temperature and SC probes. USGS gaging stations measure stage by sensing the pressure in a tube that is slowly releasing air or nitrogen through an underwater orifice. Stage, temperature, and SC data would be stored on a data logger and transferred via satellite to USGS facilities using typical USGS equipment and procedures. Discharge is estimated using the stage information and a previously determined relationship between the stage and discharge. Individual stream flow measurements with current meters and water quality sampling and laboratory analysis would be performed in accordance with normal USGS procedures and schedules, which is approximately monthly when the gages are in operation. These measurements would be used to establish and verify the stage-discharge relationship and the relationship between SC and TDS and possibly other constituents of concern. For some stations, water sampling and analysis would be more frequent (see below). Additional information on the monitoring system components follows.

Pump Station Water Quality Monitoring

Specific conductance and temperature would be continuously monitored when the system is in operation. Water samples would also be collected from the wet well weekly during system operation. These samples would be analyzed for TDS, SC, and other parameters as may be required for system operation and to verify permit compliance.

System Discharge Monitoring

A typical USGS gaging station would be established immediately upstream of the control reservoir outlet. The control reservoir outlet would provide a very stable stage-discharge relationship. This gage would operate when the outlet system is functioning.

Sheyenne River Gages

Typical USGS continuous discharge monitoring gaging stations with continuous monitoring of SC and temperature would be established on the Sheyenne River both upstream and downstream of Peterson Coulee. The gage locations would be determined following reconnaissance by USGS staff. A likely location for the downstream gage is near the bridge over the Sheyenne River about three-quarters of a mile downstream of Peterson Coulee. This bridge is located in the Northeast Quarter of Section 20, Township 151 North, Range 68 West. It may be desirable to place sheet pile across the low-flow channel to establish a hydraulic control and to provide deeper water to minimize the possibility of freezing the orifice and probes during the winter. This gage would operate continuously. If it is determined in later design phases that sheet pile is needed to control the river channel, real estate maps would be modified to show any channel improvements and flowage easements determined to be necessary.

The upstream Sheyenne River gage may be located near the bridge about 2 miles upstream of the mouth of Peterson Coulee. This site is in Section 7, Township 151 North, Range 68 West. This gage would operate continuously, when the outlet system is in operation.

Dry Lake Diversion

Normally, the new Channel A control structure would be closed in years when the outlet is operating so that flow could be diverted through the chain of lakes to Big Coulee. The gates of the new Channel A control structure would be opened in the event of significant flows (above 400 cfs) and stages (between elevations 1443 and 1446) in the Chain of Lakes. Similarly, the new Channel A control structure would be opened when Big Coulee flows exceeded 2,000 cfs. Big Coulee flows would be monitored using the previously mentioned gaging station. Historical data suggest the new Channel A control structure would likely be opened for about a month once every three years on the average.

The new control structure on the Dry Lake outlet to Mikes Lake could be operated similar to the operating plan for the original Channel A control structure. With this plan, the stoplogs would be removed on October 1 to allow Dry Lake to drain to elevation

1445 (Devils Lake levels permitting). In the spring, runoff conditions could be assessed, and if above-normal runoff is anticipated, the stoplogs could be left out until the lake was receding and had dropped below elevation 1447.5. At that time, the stoplogs could be replaced. During significant summer runoff events, the stoplogs could be adjusted following consideration of upstream and downstream impacts. Under current higher water level conditions (elevation 1447.0 and above), the stoplogs would not likely be installed and the structure would be left open, as the stoplogs would provide little control.

Cost Estimate

The cost estimate for the Pelican Lake 300 cfs outlet plan is summarized in Table 5-22. The estimated cost of the selected outlet plan used in the evaluation of alternatives earlier in this chapter, as shown in Column B, was $97,651,000. The current cost estimate, as expressed in a July 2002 price level, is $186,539,000 and shown in Column C. Adding expected inflation to this amount to the midpoint of expenditures, or the fully funded amount, is $208,228,000, as shown in Column D. Further details of the cost estimate are provided in Appendix F. A summary of cost differences between the estimate used in evaluation of alternatives and the current cost estimate (comparison of Columns B and C) is provided below. Costs are expressed in $1,000's and Engineering and Design, as well as Supervision and Administration costs for items 1 through 10 below are included in items 11, 12 and 13.

1) **- $3,853.0 for outlet features** - not including Dry Lake Diversion (reduced from $73,733.0 to $69,880.0 with more detailed analysis)

2) **+ $7,802.0 for estimated costs associated with the Dry Lake diversion** ($1,427.0 for the structural features; $2,494.0 for RE; $1,015.0 for environmental mitigation, and $2,866.0 for cultural resource surveys – more detailed analysis)

3) **+ $3,810.0 for downstream flowage easements** (were treated as annual negative benefits in evaluation of alternatives) (1)

4) **+$1,000.0 for cultural resource preservation first costs**, not including Dry Lake diversion cultural costs (more detailed analysis) (1)

5) **+$10,139.0 for present worth of long term monitoring and identified adaptive management measures** (added to first cost if considered a shared cost rather than an annual non-federal cost. Includes initial inventories and baseline development. (1)

6) **+ $3,338.0 for environmental terrestrial mitigation**, not including Dry Lake diversion mitigation costs (more detailed analysis) (1)

7) **+ $9,000.0 for cutoffs and structures for continued natural flow over meander reaches (aquatic mitigation on the Sheyenne River)** (although

these mitigation features were earlier considered most appropriately defined by monitoring during actual operation, are now included as a project first cost)

8) **+ $8,660.0 for erosion protection at 43 sites (aquatic mitigation on the Sheyenne River)** (although these mitigation features were earlier considered most appropriately defined by monitoring during actual operation, are now included as a project first cost)

9) **+$18,424.0 for a sand filter within the outlet** (included to minimize, to the extent practicable, the transfer of biota from Devils Lake to the Sheyenne River)

10) **+$1,855.0 for safety measures on lowhead dams on the Sheyenne River** (Although not recognized as a required project feature in the draft report, measures to address safety concerns at about 20 low head dams are now considered required project measures for outlet operation)

11) **+$10,300.0 for Preconstruction Engineering and Design** (PED) costs added to first cost as a cost shared element (for consistency of consideration for alternatives studied in the past, was not added to cost of each alternative)

12) **+ $14,616.0 for Engineering and Design costs** (increase due to more detailed analysis and additional project features requiring engineering and design)

13) **+ $3,797.0 Supervision and Administration** (increase due to more detailed analysis and additional project features)

(1) This item was recognized as a potential increase in the February draft report.

Table 5-22: Estimated Cost, Pelican Lake 300-cfs Outlet Plan

COST SUMMARY

($000's)

A	B	C	D	E	F
		Cost Shared Costs			
Project Features	Formulation Estimate Feb.02	July 02 Price Level Costs	Fully Funded Costs [4]	Annual Non-Federal Costs	See this item number in text for comparison of Columns B&C
01 - LANDS & DAMAGES					
Outlet	$978.0	$985.0	$1,039.0		1
Dry Lake Diversion		$2,494.0	$2,701.0		2
D.S.Flowage Easements		$3,810.0	$4,127.0		3
Lowhead Dams on Shey. River		$40.0	$43.0		10
Real Estate Mitigation		$3,287.0	$3,756.0		6
Operational Real Estate Issues				[1]	
02 - RELOCATIONS		$1,156.0	$1,275.0		1
06 - FISH AND WILDLIFE					
Envir.Mitig. (Outlet)		$94.0	$104.0		1
Envir.Mitig. (Dry Lake)		$1,015.0	$1,159.0		2
Envir.Mitig. (Downstream)	$3,900.0				6
Terrestrial		$3,951.0	$4,515.0		6
Cutoffs/Meanders		$9,000.0	$10,284.0		7
Erosion Protection		$8,660.0	$9,896.0		8
Monitoring (Baseline Establish.)					
Water Quality		$640.0	$713.0		5
Groundwater/Salinity		$543.0	$604.0		5
Erosion/Sediment		$304.0	$338.0		5
Aquatic Habitat		$333.0	$372.0		5
Aquatic/Invasive Species		$1,002.0	$1,115.0		5
Riparian Habitat		$369.0	$410.0		5
Adaptive Management Costs					
Environmental Mitigation		$3,000.0	$4,271.0	[2]	5
Monitoring (1st 10 years)		$3,652.0	$5,199.0	[2]	5
09 - CHANNELS					
Gravity Pipeline	$12,053.0	$14,158.0	$15,337.0		1
Pressure Pipeline & Reservoir	$33,837.0	$30,285.0	$32,806.0		1
Inlet Channel	$9,896.0	$6,560.0	$7,106.0		1
Dry Lake Diversion	$1,246.0	$2,673.0	$2,974.0		2
Lowhead Dams on Shey. River		$1,815.0	$2,074.0		10
13 - PUMPING PLANTS					
Pumps and Motors	$3,585.0	$3,554.0	$3,818.0		1
Pump Station and Controls	$13,384.0	$13,088.0	$14,178.0		1
Sand Filter		$18,424.0	$19,958.0	$950.0	9
18 - CULT. RES. PRESERV.					
1% of Federal Costs: All Federal	$700.0	$1,220.0	$1,394.0		4
Over 1%: Cost Shared	$9,300.0	$9,780.0	$11,175.0		4
Dry Lake Diversion Surveys		$2,866.0	$3,276.0		2
Monitoring (1st 10 years)		$296.0	$422.0	[2]	5
Potential Future Mitigation Needs		[3]			
30 - ENGINEERING AND DESIGN					
General Investigations (PED)		$10,300.0	$10,300.0		11
Construction General Funding	$4,332.0	$18,948.0	$21,448.0		12
31 - SUPERV. & ADMINIST. (7%)	$4,440.0	$8,237.0	$10,041.0		13
OPERATION & MAINTENANCE					
Outlet Operation				$1,763.0	
Additional DS Water Treatment				$50.6	
O&M of Misc. Project Features				$200.0	
TOTAL	$97,651.0	$186,539.0	$208,228.0	$2,963.6	

[1] Non-Federal sponsor responsible for unidentified, but potential future real estate costs.
[2] Costs after 10th year to be borne by non-federal sponsor. Amount dependent on need for outlet operation.
[3] Potential identification of additional cultural sites requiring mitigation to be cost shared.
[4] Includes expected inflation through the scheduled midpoint of expenditure

Economics Analysis Summary

Economic results for the Pelican Lake Outlet are summarized in Table 5-23. The without-project condition used for this analysis is that which was developed in the analysis of the Intermediate Array of Alternatives, not the newer study of the Most Likely Future Without-Project condition described previously in this section. Using the results of the newer analysis of the Most Likely Future Without Project would be expected to make no significant difference in the conclusions that can be drawn from the results of the economics analysis.

Table 5-23: Pelican Lake 300-cfs Outlet Economic Analysis

Analysis Type or Future Scenario	Total Cost	Lake Level Without Outlet	Lake Level With Outlet	Total Annual Benefits	Total Annual Net Benefits	BCR
Stochastic	$186,462	1458.74[1]	1455.85[1]	$2,595	($11,325)	0.19
Wet Future	$186,462	1460.6	1457.5	$22,554	$7,942	1.54
1455 Moderate Future	$186,462	1454.9	1452.1	$7,818	($6,328)	0.55
1450 Moderate Future	$186,462	1450	1448.9	$1,847	($12,135)	0.13
Note: All Costs are in Thousands of Dollars						
[1] Elevation based on 10 % probability of reaching or exceeding given lake level in 50-yrs.						

Upper Basin Storage

The upper basin management alternative increases the amount of available upper basin storage volume in the watershed. For analysis of this alternative, the Corps assumed that 50 percent of the total available upper basin storage could be restored as part of a viable program. Implementation of this alternative would require placement of 39,681 acres of land into an upper basin storage program. Much of this land is currently prime farmland. Previous programs have varied the duration of the storage program from an annual program to one with a 10-year contract. Therefore, an expanded program could involve contract lengths for any duration up to 10 years.

Implementation of an upper basin storage program was assumed to require the following:

A. Construction of outlet structures at some of the storage sites. These measures could vary from no construction to construction of a berm with an outlet structure, likely a gated pipe that allows flexibility for future conditions. Costs for these outlet structures would be based on site-specific conditions, and could vary from $0 up to $100,000 per site. The storage available at each site would also vary, depending on the sites selected and incorporated into the program.

B. Purchase of an easement or lease for agricultural land. Costs for easements or leases could vary widely since some lands may be more valuable agricultural areas than others (ranging from 10 to 70 percent of fee title). Land costs are currently averaging about $400 per acre (although prime farmland could be higher).

C. Program administration and negotiations, including those to acquire land through condemnation (minimum of $4,800 per tract).

D. Maintenance of the outlet structures, the cost of which would be based on the size and configuration of outlet structures.

E. Potential removal of outlet structures when the lake recedes.

The project costs for implementation of the upper basin management alternative could vary widely, depending on the sites selected for inclusion in the program. Annual costs for previous upper basin storage programs ranged from $40 to $90 per acre per year. However, it was assumed that the project costs would be computed as a one-time first cost (which includes acquisition or leasing of lands, construction of outlet structures, and other associated maintenance and/or removal costs). Therefore, these costs were computed based on an upfront first cost per acre, estimated to be at least three times the land costs (an average per acre value of $1,000). Therefore, the total project costs for the upper basin management alternative were estimated at $39,681,000. A summary of the economic analysis for Upper Basis Storage is provided in the following table.

Upper Basin Storage Economic Analysis

Analysis Type or Future Scenario	Total Cost	Lake Level Without Upper Basin Storage	Lake Level With Upper Basin Storage	Total Annual Benefits	Total Annual Net Benefits	BCR
Stochastic	$39,681	1458.74[1]	1458[1]	$773	($1,877)	0.29
Wet Future	$39,681	1460.6	1460	$3,191	$541	1.20

Note: All Costs are in Thousands of Dollars

[1] Elevation based on 10% probability of reaching or exceeding given lake level in 50 years.

Expanded Infrastructure Protection

The Expanded Infrastructure Protection Alternative was analyzed in greater detail by Barr Engineering as part of the analysis of other infrastructure features around Devils Lake discussed in the **Most Likely Future Without Project** section. This study used previous work described in the section, Intermediate Alternatives, and in Appendix B as its base. The study extended the previous work by examining further the costs and benefits of flood protection measures that would need to be implemented in the near future.   Following is a summary of the study and its results for the Expanded Infrastructure Alternative. For more detail on how the study was performed and the results of the study, please refer to the report titled *Devils Lake Infrastructure Protection Study, January 2003* by Barr Engineering.

General Information

Location

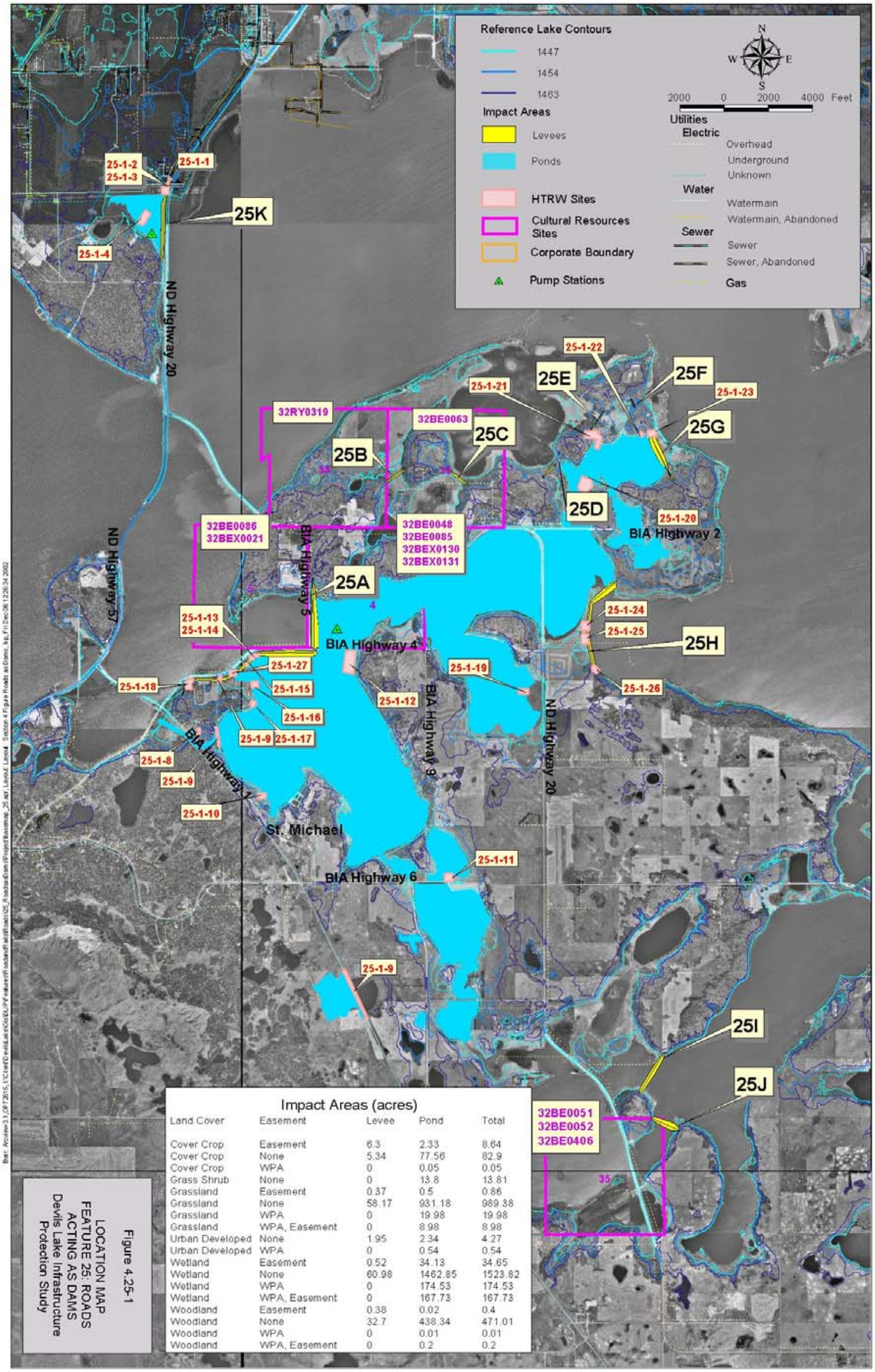
Three separate areas are currently being offered protection by a road or series of roads that are acting as dams and emergency levees. These areas include:

Mission Township Area—approximately 21 square miles of Mission Township within the Spirit Lake Reservation on the southeast side of Devils Lake between Mission Bay and Black Tiger Bay.

Highway 57/1 Area—an area of approximately one square mile within the Spirit Lake Reservation on the south side of Devils Lake south of the intersection of ND Highway 57 and BIA Highway 1.

Acorn Ridge Area—an area south of the City of Devils Lake west of ND Highway 20 and north of Camp Grafton.

Figure 5-50 shows the approximate extents of these areas, and the inundation extents at the three reference lake levels (1447, 1454, and 1463).



Land Cover	Easement	Levee	Pond	Total
Cover Crop	Easement	6.3	2.33	8.64
Cover Crop	None	5.34	77.56	82.9
Cover Crop	WPA	0	0.05	0.05
Grass Shrub	None	0	13.8	13.81
Grassland	Easement	0.37	0.5	0.86
Grassland	None	58.17	931.18	989.38
Grassland	WPA	0	19.98	19.98
Grassland	WPA, Easement	0	8.98	8.98
Urban Developed	None	1.95	2.34	4.27
Urban Developed	WPA	0	0.54	0.54
Wetland	Easement	0.52	34.13	34.65
Wetland	None	60.98	1462.85	1523.82
Wetland	WPA	0	174.53	174.53
Wetland	WPA, Easement	0	167.73	167.73
Woodland	Easement	0.38	0.02	0.4
Woodland	None	32.7	438.34	471.01
Woodland	WPA	0	0.01	0.01
Woodland	WPA, Easement	0	0.2	0.2

Figure 5-50: Expanded Infrastructure Features

Description

The length of roads currently acting as dams is approximately 7 miles. The roads acting as dams issue originated in 1995 when culverts under those roads were plugged as part of emergency measures to protect existing features. Currently, the difference in water levels on each side of the road is as much as 12 feet. This pressure difference is a potential safety hazard since the roads were not designed to be used as dams.

Three emergency levees and portions of ND Highway 20, BIA Highway 4, and BIA Highway 5 that are acting as dams protect the Mission Township area between Mission Bay and Black Tiger Bay. Portions of ND Highway 57 and BIA Highway 1 acting as dams protect the area directly south of the intersection of those two highways. The Acorn Ridge area is protected by a section of ND Highway 20 that is acting as a dam.

History of Flood Protection

In the past, flood protection in the areas protected by roads acting as dams has consisted of (1) incremental raising of the roads when the water level approaches the road surface, and (2) construction of emergency levees. The initial raising of the roads generally included plugging of drainage culverts, which has allowed the roads to act as dams holding back lake water and providing protection to areas on the opposite side of the roads. These actions are summarized in Table 5-24.

Protection Strategy by Lake Level

The most economical protection strategy has been determined to be perimeter levees constructed in the locations shown on Figure 5-50**.** To relieve the existing roads that are acting as dams, the first action would be to construct the levees to a top elevation of 1455 that would provide protection to a lake level of 1450. The second action level would raise the perimeter levees to bring them to a top elevation of 1462, which would protect to lake elevations of 1457. The third and final action level would raise the perimeter levees to bring them to a top elevation of 1468, which would provide protection to lake elevations of 1463.

Protection Strategy Description

The assumed flood protection strategies for each of the three areas is as follows:

Mission Township Area

This area would be protected by a series of levees designated on Figure 5-50 as Levees 25A through 25J. Levee25A would be constructed adjacent to the embankments of BIA Highways 4 and 5 on the land side and utilize those embankments for cofferdams on the lake side. Construction would require temporary cofferdam construction on the land side

Table 5-24: Roads Acting as Dames – History of Flood Protection

Road Raises				
Road	**Location**	**Road Surface Elevation**	**Length (miles)**	**Year Constructed**
ND Hwy 20	Acorn Ridge Area	1443	0.28	1997
ND Hwy 20	Acorn Ridge Area	1455	1.27	2001
ND Hwy 20	From ND Highway 57 to Tokio	1447.5	1.91	1997
ND Hwy 20	From ND Highway 57 to Tokio	1451.5	3.71	1999
BIA Hwy 4	From BIA Highway 1 to ND Highway 20	1450.5	1.98	1999
BIA Hwy 5	From BIA Highway 4 to ND Highway 20	1450.5	0.55	1999
BIA Hwy 6	From BIA Highway 1 to ND Highway 20	1456.9	0.90	2002
Emergency Levees				
	Location	**Crest Elevation**	**Approximate Length (feet)**	**Year Constructed**
	Section 35 (west)	1445	500	1997
		1447.6	750	1998
		1452	1000	2001
	Section 35 (central)	1445	400	1997
		1449	500	1998
		1453	600	2001
	Section 31	1445	750	1997
		1449	1000	1998
		1453	1200	2001

where water currently inundates the levee foundation area. Levees 25B, C, and G would be constructed adjacent to and on the land side of the emergency levees in those areas. A cofferdam was assumed to be required on the landside of Levee 25G. Levees 25D, E, and F are freeboard levees (base elevation is above the design lake level and height of the levee only provides freeboard protection), so can be constructed without cofferdams. A cofferdam was assumed to be required on both the landside and lake side of Levees 25I and 25J. Equalization culverts would be placed through ND Highway 20 and BIA Highways 4 and 5 to prevent those roadway embankments from acting as levees.

The internal drainage system was analyzed to assist with the sizing of an interior pump station to remove the accumulation of water from the interior area behind the levees. The analysis investigated the amount of water expected from precipitation, seepage through the levees, and groundwater seepage underneath the levees. An interior drainage system was designed to provide a minimum of 1-foot freeboard for structures and 2-foot freeboard for roads during the 100-year event. A pump station for Mission Township has been designed to maintain the interior water level at an elevation of 1442. The resulting peak flow rate to the pumping station is 222 cfs for Mission Township. To meet these requirements, a pump station with one 15-cfs capacity pump and two 20-cfs capacity pumps is required. The total maximum pumping head is approximately 26 feet.

Highway 57/1 Area

A levee to protect this area was analyzed and is estimated to cost $18.7 million. The estimated value of property protected by this levee is only a little over $1 million, and therefore it is not expected that this levee would be justifiable. It is not included in the remainder of this analysis. Highways BIA 1 and BIA 4, currently protected by the levee, could be raised to protect them from flooding.

Acorn Ridge Area

This area would be protected by a levee, constructed parallel to the portion of ND Highway 20 currently acting as a dam. Levee 25K would be constructed adjacent to the road embankment on the land side and would use that embankment for cofferdams on the lake side. Construction would require temporary cofferdam construction on the land side where water currently inundates the levee foundation area.

Similar to the Mission Township area, an interior drainage analysis was performed for the Acorn Ridge area. The resulting peak flow rate to the pumping station in order to provide 1-foot freeboard for structures and 2-foot freeboard for roads during 100-year event is 58 cfs for the Acorn Ridge area. A pump station for this area will require a single 5-cfs pump.

Environmental/Cultural Issues

HTRW

Twenty-seven potential HTRW sites identified within the general area of this feature are indicated on Figure 5-50. No facilities appear to be located within the footprint of the proposed dams and levees or within the area where the lake may expand.

Cultural

Areas of potential cultural sites are shown on Figure 5-50. Sites within the footprint of proposed dams and levees and with the area of ponding behind the levees will require field surveys.

Environmental

Areas affected by this project (for construction at the first action level) are shown in the table on Figure 5-50. Environmental Impacts are discussed in Chapter 6.

Economics of Flood Protection

Damages

For the present analysis, the flood damage estimates for Expanded Infrastructure were reassessed in order to update and more accurately characterize the nature of the damages. The primary damages include: Relocation of residences; detours; restoration and raising costs associated with roads that would be protected by this alternative; and relocation of the North sewage lagoon in St. Michael.

Costs

The updated costs of providing flood protection for roads acting as dams are detailed in Tables 5-25 and 5-26. All costs are given in 2002 dollars. The primary costs include: earthwork items associated with levees and cofferdam construction; equipment items for the pump station for interior drainage; real estate costs associated with levees and ponding areas; raising costs associated with interior roads adjacent to the ponding areas.

Economic Results

Results of the economics analysis are summarized in Tables 5-25 and 5-26. The net benefits are lower than were computed for this alternative in the intermediate array of alternatives and show this alternative to not be cost effective. This is partially due to somewhat higher estimated construction costs, but is largely due to a recent raise of BIA 6 that has reduced the benefits of this alternative.

Economic impacts of the alternatives which were evaluated in detail are summarized in Table 5-27.

Table 5-25: Expanded Infrastructure Economics Summary – Flood Protection Strategies for First Increment

		Present Worth[1]		Stochastic Analysis		Wet Future Scenario Analysis	
Protected Area	**Flood Protection Strategy Having Largest Net Benefits**	**Total First Costs for First Action Level**	**Damages Prevented**	**Average Annual Net Benefits[2]**	**Benefit-Cost Ratio**	**Average Annual Net Benefits[2]**	**Benefit-Cost Ratio**
Acorn Ridge	One Incremental Levee Raise	$ 3,404,000	$ 853,000	$ (172,300)	0.23	$ (160,800)	0.24
Mission Township Area[3]	One Incremental Levee Raise	$ 35,674,000	$ 20,763,000	$ (1,047,500)	0.55	$ (945,700)	0.57
Expanded Infrastructure Total		**$ 39,078,000**	**$ 21,616,000**	**$ (1,219,800)**	**0.52**	**$(1,106,500)**	**0.54**

Notes

1 Total first costs are actual flood protection costs, in present value. Values for damages and annual damages are also listed in present value.

2 The net benefits listed were averaged over 10,000 traces. The averages were then annualized over a 50-year period.

3 The damages prevented that are listed for Roads Acting as Dams includes: protection of St. Michael structures and detours around the lake when BIA Highway 6 and ND Highway 20 are closed. These damages represent the overall benefits to the entire Infrastructure Protection system as a whole.

Table 5-26: Expanded Infrastructure Economics Summary – Flood Protection Strategies up to Lake Level 1463

Protected Area	Flood Protection Strategy Having Largest Net Benefits	Present Worth[1]		Stochastic Analysis		Wet Future Scenario Analysis	
		Total First Costs	Total Damages Prevented	Average Annual Net Benefits[2]	Benefit-Cost Ratio	Average Annual Net Benefits[2]	Benefit-Cost Ratio
Acorn Ridge	Incremental Levee Raises	$ 15,209,000	$ 3,098,000	$ (468,500)	0.12	$ (193,400)	0.21
Mission Township Area[3]	Incremental Levee Raises	$ 87,509,000	$ 7,220,000	$ (1,410,200)	0.61	$ (166,100)	0.93
Expanded Infrastructure Total		**$ 102,718,000**	**$ 10,318,000**	**$ (1,878,700)**	**0.54**	**$ (359,500)**	**0.86**

Notes

1 Total first costs are actual flood protection costs, in present value. Values for damages and annual damages are also listed in present value.

2 The net benefits listed were averaged over 10,000 traces. The averages were then annualized over a 50-year period.

3 The damages prevented that are listed for Roads Acting as Dams includes: protection of St. Michael structures and detours around the lake when BIA Highway 6 and ND Highway 20 are closed. These damages represent the overall benefits to the entire Infrastructure Protection system as a whole.

Table 5-27: "Benefit-Cost Ratios" for Alternatives Being Evaluated in Detail

Alternatives	Stochastic	Scenarios		
		Wet Future	1455 Max. Stg. Future	1450 Max. Stg. Future
Pelican Lake 300 cfs				
Outlet (Preferred Alternative)	0.19	1.54	0.55	0.13
Infrastructure				
Protection [1]	1.07	1.86	1.33	0.93
Upper Basin				
Storage	0.29	1.20		
Expanded Infra-				
structure Protection				
(Acorn Ridge) [2]	0.12	0.21	0.15	0.13
Expanded Infra-				
structure Protection				
(Mission Twnshp) [2]	0.61	0.93	0.48	0.42

[1] Cost effectiveness of Likely Future emergency measures, as measured against No Action base condition. (does not include Roads Acting as Dams feature)

[2] Roads acting as dams feature, assuming continued infrastructure protection has already taken place as a base condition